Electronic Services - Los Angeles
M12709X

GE

Primary/Secondary/

Dry-type Substation

GEK-5655/GEI-54008B, etc.

MP MASTER
MA32663

GENERAL ELECTRIC

INSTRUCTIONS

CONTENTS

PRIMARY SUBSTATION TRANSFORMERS:

Installation and Maintenance ----------GEI-54008
Oil-Immersed Transformers ----------GEK- 5655
Automatic Gas-Control Equipment ----------GEI-54035
Insulating Oil and Transformer Drying ----------GEI-65070
Accessories ----------GEI-65077
Load-Tap Changer, Type LRT-72 ----------GEI-65094
Load-Tap Changer, Type LR-65 ----------GEK- 5651
Load-Tap Changer, Type LRT-200 ----------GEK- 5670

SECONDARY SUBSTATION TRANSFORMERS:

Secondary Substation Transformers ----------GEK- 5678
Replacement of Re-X Glass Bushings ----------GEK- 5662

DRY-TYPE TRANSFORMERS:

Ventilated Dry-Type Transformers
(All designs except 95 BIL round coil)----------GEK- 5673
Ventilated Dry-Type Transformers (95 BIL round) ----------GEK- 5658
Sealed Dry-Type Transformers (Nitrogen) ----------GEI-65054
Sealed Dry-Type Transformers (C_2F_6) ----------GEK- 5665

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT, GENERAL ELECTRIC CO., ROME, GA. 30161

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PRINTED IN U.S.A.

INSTRUCTIONS

GEK-5655 and GEI-54008B
Supplement 1

SHIPPING GAS

Unless otherwise requested by the user, this transformer has been shipped containing dry air instead of the dry nitrogen referred to in the accompanying instructions. Dry air is used for the gas cushion in liquid filled units and also to fill the entire transformer when its insulating liquid is removed for shipment.

CAUTION - The oxygen content of this air may be absorbed into the transformer insulation during shipment or storage and therefore may not sustain life! Test the oxygen content and make sure it is at least 18% before entering the tank.

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Installation and Maintenance

RECEIVING

Make an external inspection of the transformer and the boxes containing its supplies immediately upon receipt. If their condition indicates evidence of rough handling, do not unload. Before unloading, a damage claim must be filed and an inspection made by a representative of the carrier. This inspection by the carrier can have considerable bearing on the outcome of claims for internal damage found during subsequent inspection. Check the materials received against the shipping list and report any shortages to the nearest Apparatus Sales Office of the General Electric Company along with a prompt report of any damage in transit.

Transformers are normally shipped completely assembled, liquid-filled and ready to install. When shipping limitations require the removal of certain parts, the various openings are sealed with temporary covers. If the insulating liquid has been removed for shipment the transformer will be filled with *dry* nitrogen or carbon-dioxide gas. These units should normally arrive at the destination with a slight positive gas pressure (except in cold weather when a partial vacuum may exist) and are to be liquid filled before being placed in service.

If a gas-filled transformer is received with the pressure-vacuum gage indicating zero and there is no change in this reading with changes in temperature, a leak may have developed with the possibility of moisture having entered the tank. If there is reason to suspect that moisture is present, it may be necessary to dry the transformer. Questions concerning the need for drying should be referred to the General Electric Company. Information on drying procedures is contained in the leaflet on "Transformer Drying".

HANDLING

The direction of shipment shown on the Outline drawing must be observed whenever the transformer is placed in transit. The unit should always be handled in an upright position unless recommendations for special handling are obtained from the General Electric Company. Junction boxes, when provided, can normally be removed to facilitate installation of the transformer. Before moving a transformer, remove any lightning arresters that may be mounted on it.

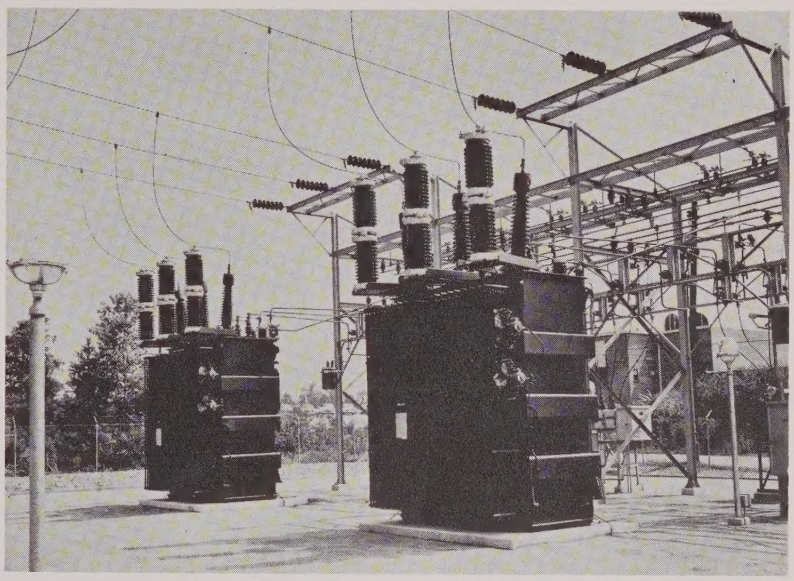

Fig. 1 Typical Installation

LIFTING

Lugs are provided for lifting the complete transformer, and where necessary, provisions are included for lifting the various parts. Lift the transformer by means of the main lifting lugs, using cables long enough to obtain cable pull angles not over 30 degrees from vertical. See Fig. 2. Use a spreader bar or lifting beam parallel to the long axis of the transformer where necessary in order to obtain proper cable angles.

To prevent buckling of the tank walls when lifting the completely assembled transformer, the cover must always be securely fastened in place. Location of the center of gravity and the approximate weight of the transformer are shown on the Outline. drawing. The weight is also given on the nameplate.

JACKING

Jacking facilities consisting of a base overhang or separate jack bosses are provided as shown on the transformer Outline drawing and as illustrated in Fig. 3. Do not attempt to raise a transformer by placing jacks under drain valves, pipe connections or other attachments.

ROLLING OR SKIDDING

The transformer can be rolled (see Fig. 4) or skidded by means of pulling holes provided at the base. Cables can be attached with a hook or clevis, or by placing a loop around bolts in the holes. Restraining cables should be used when rolling downgrade.

STORING

If the equipment is to be subjected to storage it is preferable to prepare

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GENERAL ELECTRIC

Fig. 2 Lifting

the unit for service prior to the storage period. If this is not convenient, all supplies such as bushings, radiators, accessories, etc., should be stored indoors. To avoid moisture damage, unpack boxes or crates containing excelsior and open those covered with paper to provide free ventilation.

Before placing a sealed-tank transformer in storage, make sure the insulating liquid is at its proper level, add dry nitrogen in the gas space until the pressure reaches 3 psi, and then seal the unit. Before placing the transformer in service after a period of storage, reestablish the transformer seal as explained under "Sealed-Tank Transformers". Refer to separate instructions for storage of transformers utilizing other types of oil preservation systems. Make sure that the insulation and insulating liquid are dry before energizing a transformer after continued idleness. (See separate instructions on insulating liquids and transformer drying.)

SPARE TRANSFORMERS

To facilitate emergency installation of spare transformers, they should be maintained during storage as though they were in service. Make periodic inspections of the liquid level, its dielectric strength, and when furnished, fans, pumps, alarms, control circuits, and load-tap-changing equipment. Also check the pressure gage to make sure the transformer seal is being maintained and inspect junction boxes and other compartments for evidence of moisture condensation.

GAS FILLED SHIPMENTS

Transformers shipped gas filled may be stored in that condition providing a positive gas pressure is maintained. Add gas of the same type as that used for shipment as identified by a tag enclosed with the shipping list. Fig. 5 shows two charts that indicate the proper gas pressure to hold under various conditions of altitude and temperature. If the storage period extends into warm weather, release gas as required to limit the pressure to 5 psi. (Transformers equipped with pressure-vacuum bleeders will do this automatically.)

Nitrogen gas can be obtained from the Air Reduction Sales Company in cylinders containing 220 cu. ft. of gas at atmospheric pressure, compressed to 2000 psi at 70F. Orders for this gas should specify "Special dry nitrogen to General Electric specification D27A3A".

Carbon dioxide gas can be purchased in cylinders containing 450 cu. ft. at atmospheric pressure, compressed to 850 psi at 70F. Cylinders are available at sales outlets of the Liquid Carbonic Corporation, whose main office is in Chicago, Ill., or the Pure Carbonic Company with its main office in Newark, N. J. Orders for this gas should specify *dry* industrial carbon dioxide gas.

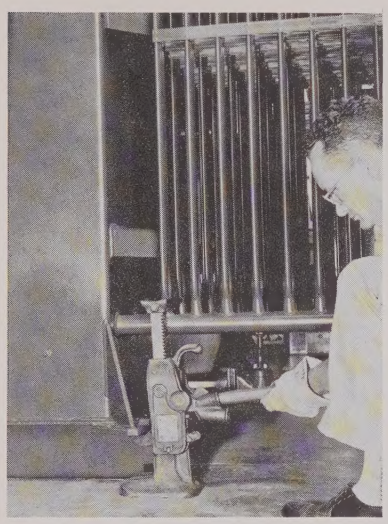


Fig. 3 Jacking

The proper regulating valve should be obtained for introducing gas into the transformer. Before transferring any gas, invert the cylinder for 24 hours in an ambient temperature not lower than 20C. With the cylinder still inverted, open the valve for a few seconds to remove any moisture that might accidentally be present. Return the cylinder to an upright position for transferring the gas and discontinue its use when the pressure drops to 150 psi.

SEALED-TANK TRANSFORMERS

Sealed-tank transformers are provided with a gas space above the insulating liquid. This space serves to cushion the tank against changes in pressure created by expansion and contraction of the liquid. Under normal operating conditions the space remains sealed from the atmosphere, thus protecting the insulating liquid against contamination and maintaining its dielectric strength at a high value over a long period of time. When the space available in the main tank is limited, additional space is sometimes provided by piping down to the channel braces or, occasionally, by the use of a separate expansion tank.

Oil-filled units are equipped with a pressure-vacuum bleeder which maintains the internal pressure or vacuum within the operating limits shown on the transformer nameplate. It is seldom required to operate, however, and functions primarily as a safety device. For further information refer to the instructions pertaining to that device.

APPLYING THE SEAL

After the installation and assembly work has been completed, establish the tank pressure as follows:

Liquid Temperature Degrees C	Approximate Starting Pressure, psi	
	Without Bleeder	With Bleeder
25	0.0	3
30	0.5	3
35	1.0	3
40	1.5	3

If it is necessary to reduce the tank pressure, the excess can be bled off through the pressure test valve. If a transformer without a bleeder is sealed when the temperature is below 25C, it should be resealed at the proper pressure as soon as the temperature rises above 25C. This will avoid excessive pressures at normal operating temperatures.

Flushing

Flushing of the gas space in oil-filled transformers is not considered necessary since the oxygen in the air combines chemically with the oil during the first few weeks of operation. In Pyranol® filled transformers there is no chemical reaction, but the oxygen does not present an explosion hazard because of the non-flammable characteristics of the Pyranol insulating liquid.

However, if it is the user's practice to purge the gas space, this can be done by removing the pipe plug from the vent hole on the manhole cover (or main tank cover) and admitting *dry* nitrogen gas through the transformer pressure test valve. Allow the nitrogen to flow until the escaping gas tests five percent oxygen or less. After 24 hours, analyze the gas again and repeat the flushing operation if necessary. No more than three flushings should be required.

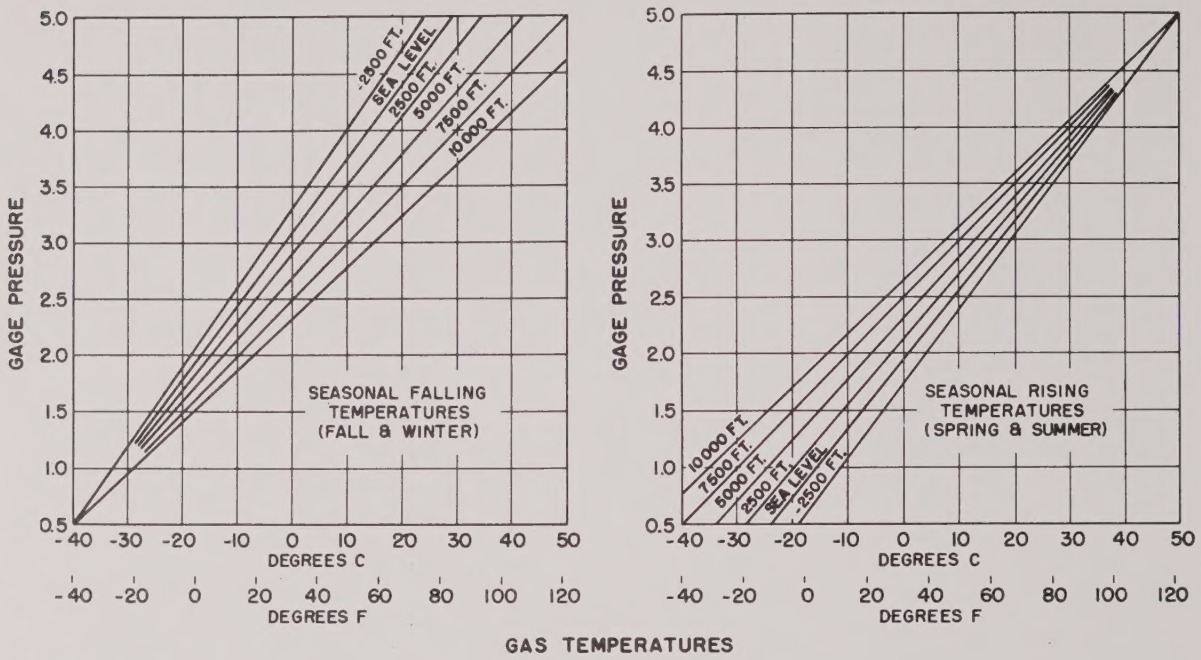
OTHER PRESERVATION SYSTEMS

Information on other types of oil preservation systems such as conservators, automatic-gas-control equipment, and gas-oil-seal units will be found in applicable instructions supplied when that equipment is furnished.

INSTALLATION

Provide a strong, level foundation, preferably of reinforced concrete. For transformers having flanged wheels, rails must also be provided. When key in-

Fig. 4 Rolling



Example of use of graphs:

Altitude — sea level, present temperature — 15 C

If seasonal falling temperatures, gas pressure at 15 C (from curve) — 4.1 psi

If seasonal rising temperatures, gas pressure at 15 C — 2.8 psi

Fig. 5 Gas pressure to be applied at various temperatures and altitudes to maintain an internal pressure between 0.5 and 5 psi

terlocks are used with disconnect switches, circuit breakers, tap changers, etc., make sure all components using the same key are installed in the same circuit.

Select a location where air can circulate freely. If the transformer is to be installed in a compartment or vault, provide adequate ventilation to avoid overheating. At high altitudes, decreased air density reduces transformer cooling efficiency and lowers bushing arc-over voltages. If transformers are to be moved to an elevation above 3,300 feet, consult the nearest Apparatus Sales Office of the General Electric Company relative to their suitability for operation at the higher altitudes. Transformer finishes and components are designed for normal life in a non-corrosive atmosphere. Atmospheres which include corrosive agents may require additional protective measures.

Transformers shipped gas filled are to be liquid filled before being opened for assembly or inspection, as outlined under "Liquid Filling". If the transformer is to be filled under a high vacuum it may be opened prior to filling as explained under "Vacuum Filling".

CAUTION—Before removing a manhole cover, shipping plate, or other device, vent the transformer to atmospheric pressure. Do not enter the transformer until the gas space has been flushed with fresh air or a suitable oxygen supply is available.

Temporary shipping parts are marked red and must be removed before placing the transformer in service. These may include both internal and external parts such as braces, bushing terminal block supports, the tape used to secure terminal board links, covers, breathers, or pipe caps and plugs.

All parts removed for shipment are identified by appropriately marked copies of the shipping list. These parts are to be installed as shown on the transformer Outline Drawing. When working on a transformer with the cover open, exercise care to see that no foreign matter is dropped into the tank. It is recommended that workmen tie tools to the tank before using them inside. All parts within the tank and all parts to be installed within the tank should be kept warmer than the surrounding air to prevent condensation.

Complete information on the accessories can be found in the leaflets pertaining to those devices. The danger of breaking bushings can be minimized by installing them last. For wiring details, refer to the transformer Connection Diagram. When installing breathers, be sure they are turned down to prevent entrance of moisture. Use G-E Compound A15A11A or Teflon tape to seal threaded joints. When installing radiators, keep the valves closed until ready to complete the liquid filling or to lower the liquid level for an internal inspection. When a radiator has been filled do not close both top and bottom valves at the same time unless the radiator is to be *immediately removed*. Damaging hydrostatic pressures can be generated by temperature changes when both valves are closed.

INSPECTION

After installation work has been completed and before energizing the transformer, make an internal and external inspection for loose, damaged, and displaced parts. A weighted sealed beam lamp of the pyrex glass type will aid in making an inspection through the insulating liquid. Enclose the lamp in fine mesh wire before lowering it into the tank to prevent scattering of the glass in case the lamp is accidentally

broken. It is recommended that a lamp cord having synthetic insulation be used and that the lamp be immersed in the liquid before being turned on.

A more thorough internal inspection can be made by lowering the insulating liquid to the top of the core. Be sure the windings and end insulation are not exposed to the air. On transformers shipped gas filled this inspection can be made prior to the final filling or in the case of high vacuum filling, before any liquid has been added. See "Liquid Filling".

Examine the core, coils, and underside of the cover for signs of moisture and conduct dielectric test of the insulating liquid in the main tank and all compartments. If evidence of moisture is found or if the windings or end insulation have been exposed to the atmosphere, it may be necessary to dry the transformer. Questions concerning the need for drying a particular transformer should be referred to the nearest Apparatus Sales Office of the General Electric Company. For information on drying procedures refer to the instructions on "Transformer Drying".

If the liquid level is lower than that called for on the transformer nameplate (measured from the top of the manhole flange), the required amount of liquid should be added through a manhole as described under "Final Filling".

Check List

The following list can be used as a general guide for inspecting, checking, and testing the various accessories and other features of the transformer, when provided. For detailed information, refer to the applicable instructions.

1. Make certain all parts shipped separately have been assembled.

2. Make an internal inspection for loose or damaged parts and check:
   - A. For correct terminal board connections as shown on the nameplate.
   - B. To see that all terminal nuts and connecting links are tight, including the load-tap-changer terminal board.
   - C. Obvious lead clearances.

3. Check to see that all temporary shipping braces, etc. (items painted red) have been removed.

4. Be sure radiator valves are open.

5. If desired, make a low voltage ratio test on each tap changer and LTC position.

6. Operate the tap changer to see that the wedge seats itself properly in each tap position. The tap changer drive will be at the center of a high torque region when the wedge is in an operating position.

7. Check the gas system on transformers equipped with an automatic gas seal.

8. Inspect accessories and control equipment and check wiring and alarm circuits.

9. Check fan operation, making sure that the number, type, and location agree with the transformer Outline drawing.

10. Check operation of pumps (the liquid flow gage will not indicate oil flow if pump rotation is incorrect.)

11. Inspect load-tap-changing equipment as follows:
   - A. Open the compartments and check for loose or damaged parts, including cracked porcelains, etc.
   - B. Make sure the breathers have been installed on the liquid-filled switch compartment.
   - C. Operate through all positions by hand and check for binding.
   - D. Operate through all positions by motor and check the limit switches, position indicator, operation counter, automatic features, and dynamic braking (when furnished).

12. Make sure all gasketed parts having grooves or stops are drawn up metal to metal and tighten all valve stem nuts.

13. Check the level and dielectric strength of the insulating liquid in the main tank and in all separate compartments such as junction boxes, throats, disconnect switches, potential devices, etc. The level of the liquid in the main tank should be measured from the top of the manhole flange and compared with the dimension given on the nameplate.

LEAK TESTS

Inspect the entire transformer for evidence of leaks and make the following pressure test. Introduce *dry* air or nitrogen through the pressure test valve until the tank pressure reaches a value just slightly less than the maximum operating pressure shown on the nameplate. Seal the transformer at this pressure and make an examination for leaks over a period of 12 hours. Leaks above the liquid level can be located by applying a solution of soap and glycerin to all gasketed joints, pipe fittings, etc.

PAINT FINISH

Use an oil solvent to thoroughly remove any oil on the outside of the tank or on gaskets. This will avoid the false impression of leaks in the future. In the case of Pyranol insulating liquid it will be necessary to use naptha or benzine to remove all traces of the liquid because of its tendency to soften the paint.

When the installation has been completed, clean all damaged paint areas and, using the touch-up paint provided, apply one primer coat and two finish coats. Allow at least 16 hours drying time between coats. Examine the paint finish at periodic intervals for signs of deterioration and clean and repaint as required.

CONNECTIONS

Transformers having internal terminal boards are normally shipped connected for the highest rated voltage. When shipped otherwise, a tag fastened to the nameplate will indicate the connections that have been made. Before applying voltage to a transformer, see that all connections are tight and that the windings are connected for the desired voltage. Make no connections except those authorized by the nameplate.

TANK GROUNDING

Ground the tank permanently and effectively by means of the ground pads provided at the base of the tank. A good, permanent, low-resistance ground is essential for adequate protection. A poor ground may be worse than none at all as it gives a sense of false security to those working around the equipment and may result in serious injury or damage to the transformer.

SYSTEM GROUNDING

Transformers having reduced insulation at the neutral end of a winding or in a neutral bushing can be operated with the neutral either solidly grounded or grounded through an impedance which will limit the low frequency and impulse voltages from neutral to ground to values consistent with the insulation levels shown on the nameplate.

LINE AND LOAD CONNECTIONS

Make line and load connections tight and see that there are no strains on the terminals which will cause the joints to become loose. Provide sufficient flexibility in the leads to prevent porcelain breakage caused by expansion and contraction. The bushings will support a considerable weight of conductor, but long spans of unsupported conductor, especially if outdoors, should be avoided. Refer to the bushing instructions for more detailed information.

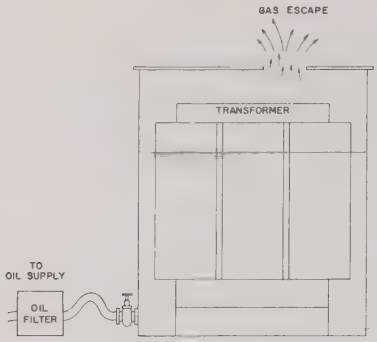


Fig. 6 Filling without vacuum

Single-phase transformers suitable for Y operation on either the high or the low voltage side may be so connected on either side, but not simultaneously on both sides unless precautions are taken to suppress third harmonic voltage.

LIGHTNING PROTECTION

Protect every transformer from lightning disturbances by some form of direct stroke protection and by approved lightning arresters that are installed as near as possible to the transformer and are directly and effectively grounded. The incoming line should be brought to the arrester first and then to the transformer bushing.

LIQUID FILLING

Vacuum filling is required on all transformer with a basic impulse insulation level of 350KV and above as shown on the nameplate. This requirement applies to the initial filling and at any time thereafter if the coils and/or end insulation are exposed to the atmosphere. All other transformers can be filled without vacuum. However, if the user prefers, any unit can be vacuum filled providing the vacuum drawn does not exceed the limit for which the tank is braced as shown on the transformer nameplate.

Detailed information on sampling, testing, and handling procedures for insulating liquids are contained in separate instructions. The following paragraphs describe procedures to be used in oil filling. The "Filling Without Vacuum" method may also be used in those few cases where Pyranol® insulating liquid has been removed for shipment. When transferring the liquid to the transformer, it should be passed through a filter press to remove any undetected moisture or sediment. The filter system must be tight to prevent air from being drawn into the pumping equipment on the intake side.

Once oil filling has started it should be continuous. If work is to be done inside the transformer or an inspection is to be made, discontinue filling when the coils and end insulation are covered, or in the case of vacuum filling, when 85% of the amount of oil called for on the nameplate has been added.

WARNING— Static charges can be developed when transformer oil flows in pipes, hoses, and tanks. To accelerate dissipation of the charge in the oil, ground the filter press, transformer tank, and all windings (if accessible) during the oil pumping and filtering operation. Since conduction through the oil is slow, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped.

If the bushings were removed for shipment and the windings cannot be grounded during the initial oil filling, discharge the windings with a ground stick before inspecting the interior or installing the bushings.

Arcs can occur from the free surface of the charged oil even though the previous grounding precautions have been taken. Therefore explosive gas mixtures should be removed from all containers into which oil is flowing.

FILLING WITHOUT VACUUM

The transformer should not be opened until ready to proceed with the filling operation. To fill the unit, pump filtered oil in through the drain valve while exhausting the shipping gas through a manhole opening as shown in Fig. 6. (*CAUTION—Vent the transformer to atmospheric pressure before removing the manhole cover.*) Small bubbles may prevent the transformer from reaching its full insulation strength for some time after being filled and therefore a waiting period should be observed to give the bubbles a chance to rise to the surface or be absorbed by the oil.

Before applying full voltage, transformers shipped *nitrogen* filled should be allowed to stand for a minimum of 24 hours after filling and as long thereafter as possible. *Carbon dioxide* units should be given at least 48 hours and preferably much longer. The oil level will drop slightly as the bubbles dissipate and the oil permeates various parts of the transformer, so before placing the unit in service the level should be checked and corrected.

VACUUM FILLING

The transformer may be opened prior to vacuum filling providing there is no free water in the form of rain or heavy fog nor a threat of any precipitation at the time the unit is opened. If the core and coil assembly is exposed to the atmosphere during inspection or installation, the total exposure time should not exceed 24 hours. A positive nitrogen-gas pressure must be established following inspection and each time the transformer is sealed at the end of a working day.

Laboratory tests indicate that once the cellulosic insulation in the transformer has been oil soaked, it absorbs moisture very slowly. If the entrance of free water is avoided, the only moisture to enter the transformer will be the result of surface condensation and this can be withdrawn before oil filling by the application of a high vacuum.

Connections

Connect the oil line to the top filter press valve on the transformer and install a 100 psi pressure gage next to the valve as shown in Fig. 7. A high reading gage is suggested to prevent damage should the oil filter be started with the valve shut. Introducing oil at the top of the transformer serves to deaerate it as it falls and also aids in the removal of any free air entering through the oil handling equipment.

A high efficiency vacuum pump having a piston displacement of approximately 50 cubic feet per minute will generally be adequate for most transformers. The vacuum line is to be connected at the top of the transformer through a cut-off valve. If suitable pipe connections are not already available, construct a temporary plate for one of the cover openings and install the necessary piping on this plate. The vacuum connection should be located as far away from the oil inlet as possible and piping should be kept short.

Precautions

1. It is undesirable to draw a vacuum on a partially filled transformer. The vacuum will tend to release any gases dissolved in the oil and the resulting bubbles can easily become trapped, forming voids in the insulation system. If the core and coils are already covered, filling may be completed through a manhole with a hose as ex-

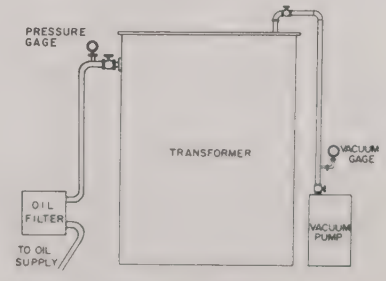


Fig. 7 Filling under vacuum

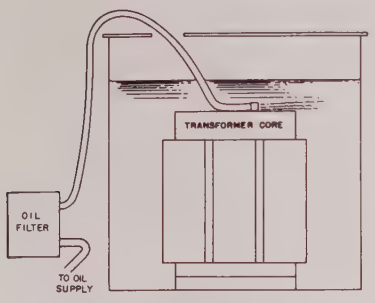


Fig. 8 Method used to complete filling

plained under "Final Filling". Otherwise, the unit should be drained and then refilled under vacuum.

2. All leaks must be detected and repaired before the filling process is started in order to prevent the entrance of air or moisture as the vacuum is drawn.

3. Before filling a sealed-tank transformer under vacuum, remove the pressure-vacuum bleeder and replace it with a pipe plug.

4. Automatic-gas-control equipment must have the gas regulator and supervisory equipment protected by closing the feeder valve between the sump compartment and the transformer.

5. Gas-oil-seal transformers must have the expansion tank isolated by removing the ½" pipe plug from the block where the piping enters the transformer tank and inserted a ⅛" pipe plug into the opening provided for sealing.

6. Oil-filled compartments, such as the tap selector portion of load-tap-changer equipment, disconnect switches, junction boxes, etc., must not be subjected to more than a 5 psi vacuum.

7. Conservator-type transformers require a slightly different filling procedure. See "Conservator-Type Transformers".

Filling

If the core and coil assembly has not been exposed to the atmosphere before oil filling, draw a vacuum not to exceed 25 millimeters of mercury absolute pressure and hold for a period of 4 hours prior to and during the oil filling. If the unit has been exposed, surface moisture should be removed by drawing a vacuum of 2 millimeters absolute pressure and holding for four hours plus a period of time equal to the exposure time. Keep the vacuum pump running during the holding period if necessary in order to maintain the required vacuum. The maximum hold time will be 28 hours.

After the vacuum has been held for the required period of time, open the top filter press valve on the transformer and start the filter press equipment. Maintain the vacuum on the transformer while filling and limit the rate of oil flow to a maximum of 25 gpm. In order to avoid the possibility of drawing air into the system, the top filter press valve should be adjusted to maintain a positive pressure on the oil line. If difficulty is experienced in holding vacuum during the oil filling, further throttling of the oil flow may be necessary. After the transformer has been filled, allow it to stand for at least 24 hours before energizing.

Conservator-Type Transformers

When vacuum filling conservator-type transformers proceed as follows:

1. Connect the oil line to the pipe nipple provided on the cover of the transformer.

2. Avoid drawing a vacuum on the conservator tank by closing its shut-off valve (or by installing it later).

3. Vacuum fill with 85% of the main tank oil.

4. Add the remainder of the main tank oil as explained under "Final Filling".

5. Seal the unit and complete the filling through the conservator tank as explained in separate instructions on conservator-type transformers.

FINAL FILLING

When adding oil after the windings are covered and the initial filling has been discontinued, or after the level has been lowered for inspection or assembly, it should be added through a manhole. Lay the hose on top of the core and direct the oil flow parallel to and along the top of the core as shown in Fig. 8. Filling in this manner minimizes aeration of the oil and the possibility of entrapping air in the insulation or coils below the level of the initial oil filling. As a final step before placing the unit in service, remove any oil spilled on the outside of the transformer to avoid the false impression of a leak in the future.

GASKETS

Gaskets used to maintain the transformer seal have been selected for their ability to resist deterioration by the insulating liquid and to avoid contamination of the liquid. Gaskets made of nitrile (Buna N) and fluorinated rubber (Viton, Fluorel, etc.) are used on oil-filled transformers and silicone and fluorinated rubbers are used on Pyranol-filled units. Gaskets provided with the transformer or as replacement items are especially compounded to G-E specifications and substitution of improper materials for these gaskets will result in unsatisfactory joint life.

Replacement or spare gaskets can be purchased to size through the nearest Apparatus Sales office of the General Electric Company. Identify the parts wanted as explained under "Renewal Parts". If an extended storage period is anticipated it is recommended that spare gaskets be placed in a clean, dark place away from high temperatures.

All of the gaskets used to maintain the transformer seal can be reused many times unless damaged. Before installing a new gasket or replacing an old one, thoroughly clean the gasket surfaces. Although in most cases no sticker is required, the compound furnished with the gaskets may be used if desired. All gaskets are to be installed with their widest dimension next to the gasket surface and in the case of scarfed gaskets made from strip material it may be necessary to use a sticker to hold them down. Square gaskets with scarfed joints should be installed with the scarf laying flat, in a position where the compression forces will clamp the joint together, rather than on edge where clamping tends to open the joint and produce leaks. Compress the gasket approximately one-third, or to the stops when provided in either the mating parts or in the gasket itself. Gaskets are compressed to the stops when there is a noticeable increase in the torque required to tighten the bolts. A leak test is recommended following the opening and closing of any gasketed joint affecting the transformer seal.

WEATHERPROOF JOINTS

If a removable, air-filled compartment is shipped separately, a length of sponge rubber gasket is furnished for the purpose of weatherproofing the joint between the compartment and the transformer. Install this gasket just outside the mounting studs or bolt holes and for the best weather-resistant joint allow the piece across the top to overlap the two side pieces.

To install a sponge rubber gasket, clean the surface on which it is to be mounted and apply a thin coat of the adhesive furnished to both the metal and the gasket. (*Do not* apply adhesive to the edges or outside surface of the gasket). Allow the adhesive to dry until it is no longer tacky and then press the gasket against the metal with enough pressure to make a good contact.

When a retaining strip is provided

the gasket should be assembled with its inner edge in contact with the strip. Tighten the gasket down to this stop or in the absence of a stop, compress it to approximately ½ size.

MAINTENANCE

Certain items on the transformer should be inspected at regular intervals. The following table can be used as a general guide under average conditions, although the actual frequency of inspection should be adjusted for each application according to the importance of continuity of service and as experience dictates. Refer to the instructions pertaining to a particular device for detailed information on maintenance or testing of that item.

ITEMS TO INSPECT	SCHEDULE
Ambient Temperature	H
Liquid Temperature	H
Winding Temperature	H
Load Current (amperes)	H
Voltage	H
Pressure Gage (tank)	D
Liquid Level	D
Insulating Liquid	Note 1
Alarm and Control Circuits	M
Ground Resistance	Q
Automatic gas-control equipment	
1. Transformer gas-pressure gage	D
2. Gas Cylinder content	D
3. Low-pressure alarm circuit	Q
Load-Tap-Changer	Note 2
Fans	M

H-Hourly D-Daily M-Monthly Q-Quarterly

Note No. 1 Test after the first few days, six months, one year, and then yearly. Filter when need is indicated by laboratory tests.

Note No. 2 Refer to the load-tap-changer leaflet.

EXTERNAL CLEANING

The bushing porcelains should be inspected at regular intervals and kept reasonably free from dust and dirt. In locations where abnormal conditions prevail, such as sand storms, salt deposits, cement dust, acid fumes, etc., a special hazard may exist, and the bushings should be cleaned regularly to avoid accumulations on the external surface which may result in flashover.

Keep the heat radiating surfaces of the transformer clean. Transformers, especially those near the seacoast, should be kept painted to prevent corroding or rusting of metal parts. Periodically inspect the small screened openings in the breathers and/or pressure-vacuum bleeder to be sure they are clean and operating.

All ground buses and all wiring leads to ground must be kept in good condition. Climatic and topographical conditions largely determine the inherent characteristics of the ground. Proper relay operation in a system depends on the ground resistance being low at all times. A low ground resistance is of such importance that it should be measured quarterly.

CIRCUITS AND CONTROL EQUIPMENT

Inspect monthly for the following:

- Control-circuit voltage
- Collections of dirt or gum
- Excess heating of parts—evidenced by discoloration of metal parts, charred insulation, or odor
- Freedom of moving parts (no binding or sticking)
- Corrosion of metal parts
- Remaining wear allowance on contacts
- Excess slam on pickup
- Proper contact pressure
- Loose connections
- Condition of flexible shunts
- Worn or broken mechanical parts
- Excessive arcing in opening circuits
- Excessive noise in a-c magnets
- Evidence of dripping water or liquids falling on controls
- Operation—including proper functioning of timing devices, etc.

Grease, oil or sticky dirt may be removed with a lint-free cloth moistened in a nonflammable cleaning fluid. Do not soak the parts with the cleaner; but use just enough to loosen grease or dirt so that it can be wiped off. For cleaning small parts, a small paint brush dipped into the cleaning solution is good for getting into corners and crevices.

INTERNAL MAINTENANCE

Under normal operating conditions, internal inspections should not be necessary except when a need is indicated by laboratory analysis of samples of the insulating liquid. If laboratory tests show signs of sludging in an oil-filled transformer, the internal parts should be thoroughly cleaned. Untanking is usually necessary to remove the sludge in the windings. Cleaning may be done by forcing oil under pressure from a nozzle onto the internal parts. Great care should be exercised in order not to damage any insulating material. Recondition or replace the old oil, referring to the applicable leaflets. Severe cases of sludging should be referred to the nearest Apparatus Sales Office of the General Electric Company for recommendations.

Untanking

If it should ever become necessary to untank the core and coils, disconnect any wiring from cover outlets and remove any parts which are connected between the cover and the sides of the tank. If the transformer has a welded cover, remove the weld bead as explained under "Removing and Rewelding Covers" before opening the unit. Drain the insulating liquid and remove or disconnect the bushings, current transformer secondaries, winding-temperature devices, liquid-level gage, and any other parts which might get damaged or interfere with removal of the core and coils. Refer to the instructions on wedge-type tap changers and remove the tap-changer operating mechanism, making sure that it is first set on Position 1.

If the transformer is provided with load-tap-changing equipment, disconnect all leads from the windings and reactor to the LTC terminal board. Make sure all leads are tagged in order to aid in proper reassembly. *Some transformer tanks may be unstable if the core and coils are removed from the tank and the load-tap-changer equipment is left in place.* It is recommended that the stability of the tank be checked as the core and coils are lifted and that blocking be added under the LTC compartment if required.

The steel wedges or anchor blocks between the top core clamps and tank wall must be removed before the core and coils can be taken out. Carefully lift the core and coils out of the tank, using a lifting beam or spreader (See Fig. 9) when needed to keep slings from interfering with the superstructure or when a series transformer is mounted on the end of the core and coil assembly. The untanking height is shown on the transformer Outline drawing. Since the clearance between the core and coils and the tank wall is usually small, exercise care to prevent damage to parts such as pressboard casings and lead supports.

Retanking

When replacing the core and coils, follow the procedure outlined above in reverse order. Note that locating pins are welded to the base of the transformer tank to prevent the core and coils from shifting. The holes provided in the cross-bars or angles under the bottom core clamps must positively fit over these locating pins. After the transformer is completely reassembled, it may be necessary to dry the unit. For information on how to conduct a drying run, refer to the instructions on transformer drying. Questions on the necessity of drying a particular transformer should be referred to the nearest Apparatus Sales Office of the General Electric Company.

LOAD RECORDS

Daily records of load and voltage on

the transformer should be checked occasionally to see that the transformer is operating within the prescribed limits and is being used efficiently. When tapped windings are used, over-excitation and excessive core loss can result from improper tap connections.

TEMPERATURE RECORDS

Changes in indicated temperatures are often the only means by which the operator can detect the occurrence of abnormal conditions within the transformer. Operating temperatures, therefore, are important from this standpoint and should be carefully recorded and examined as often as practical, along with coincident records of ambient temperature, load and excitation. Examination of such records will enabe the operator to protect the transformer from extended periods of abnormal operating temperatures which may affect its life expectancy. If a temperature is indicated which is more than 5 C higher than attained under the same conditions of load, excitation, and ambient temperature when the transformer was first placed in service, notify the nearest Apparatus Sales Office of the General Electric Company.

OPERATING TEMPERATURE

The operating temperature of the transformer should not exceed values given in ASA Standard C57.12-1958 for Transformers, Item 12-05.110. Temperatures above those recommended will result in accelerated deterioration of the liquid and may or may not affect the insulation, depending upon the hottest-spot temperature of the windings.

The top-liquid temperature alone is NOT recommended for indicating safe overload conditions within the apparatus. Hottest-spot temperature readings will give a more accurate indication of load conditions within the equipment, because the hottest-spot temperature rise over the top-liquid temperature varies widely for different methods of cooling and different loads. For continuous overload operation of the transformer, refer to the ASA Loading Guide, Appendix C-57.92. If there is doubt about a specific piece of equipment, contact the nearest Apparatus Sales Office of the General Electric Company for advice.

INSULATING LIQUID

The dielectric strength of the insulating liquid should be checked after the first few days of operation, again after six months, and at the end of one year. After one year, a periodic sampling and testing schedule should be established at intervals of one year or less, dependinng on local climatic conditions, the load on the transformer and the importance of minimizing interruptions. Refer to the instructions pertaining to transformer insulating liquids for information on the techniques of sampling and testing and the method of filtering when laboratory test indicate the need.

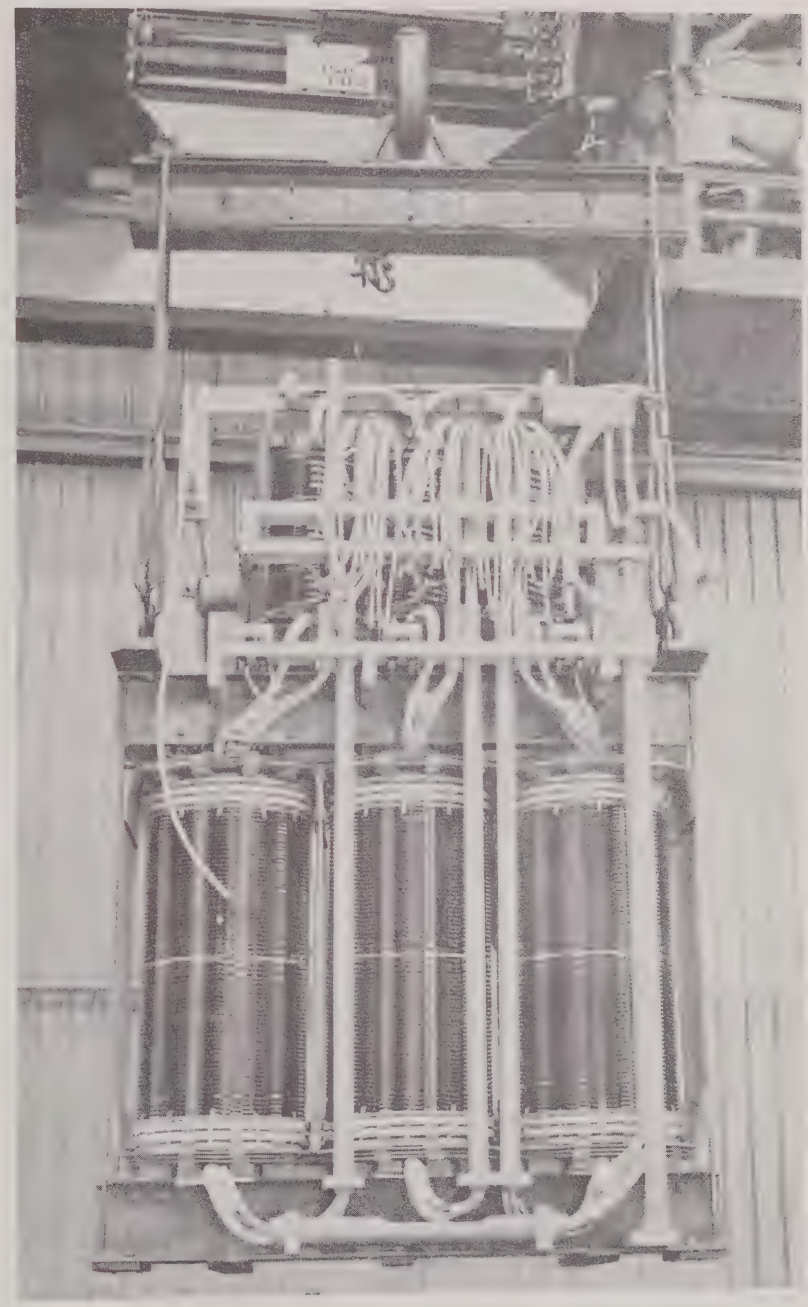


Fig. 9 Transformer core and coils showing use of lifting beam

REMOVING AND REWELDING COVERS

Welded covers can be removed by chipping out the weld bead with diamond-point chisels and a pneumatic hammer or by the oxygen gouging method. The latter method is considerably faster and is recommended for all welds of 5/16" and over where adequate precautions can be taken for the fire hazard which exists with oxyacetylene cutting operations.

When removing the weld bead, the cover should be clamped to the tank flange to hold it in place and prevent chips or welding slag from entering the transformer. Protect all openings against the entrance of foreign matter. Before

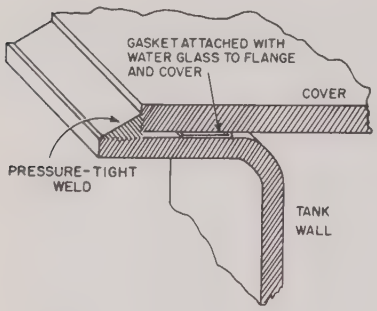


Fig. 10 Tank and cover arrangement

oxygen gouging on oil-filled transformers, thoroughly flush out the air space inside the tank with *dry* nitrogen or carbon dioxide gas and maintain a small flow of the gas during the gouging operation. (This precaution is not necessary for transformers filled with Pyranol insulating liquid).

The entire weld may be removed in one pass, providing care is taken to avoid deep gouging of the edge of the cover or tank flange. The joint should be ground or chipped clean for rewelding before the cover is removed. Oxyacetylene cutting torch equipment is necessary with gouging tips similar to Air Reduction Style No. 183. For best performance of the gouging operation, a cutting torch similar to Airco Series 3000 having a graduate control of the high-pressure oxygen flow is recommended. Tip sizes and gas pressures recommended for various fillet weld sizes are as follows:

Fillet Weld Size	Tip Size	Oxygen Pressure	Acetylene Pressure
5/16-in.	No. 8	60 psi	8 psi
3/8 and 7/16-in.	No. 10	70 psi	9 psi
1/2-in. and up	No. 12	75 psi	9 psi

REWELDING THE COVER

Before replacing the cover, remove all traces of dirt, grease, and insulating liquid from the areas to be welded. Cement a gasket to the tank flange or cover by applying a coat of water glass (sodium silicate) to both surfaces. The gasket should consist of a piece of 3/8-inch loose-twist glass or asbestos roving or a strip of 1/16 x 1½-inch dry asbestos folded to make it ¾-inch wide and should be located approximately ½-inch from the outer edge of the cover. See Fig. 10. Clamp the cover to the flange during the welding operation to compress the gasket and prevent slag or spatter from entering the transformer.

Seal all openings to prevent any possibility of welding spatter entering the transformer. For oil-filled transformers, thoroughly flush out the air space with *dry* nitrogen or carbon dioxide and maintain a small flow of gas during the welding operation.

The arc welding process, using 3/16 or ¼ inch diameter electrodes, is recommended for rewelding the cover. The fillet should be built up with a series of passes to a thickness comparable to that of the original weld. In order to make a pressure tight joint, slag and spatter should be completely removed before each succeeding pass and at each point where the arc is interrupted.

When the welding has been completed, remove all scale and pressure test the joint as explained under "Leak Test". After a satisfactory test, clean the weld and adjacent surfaces and apply one primary coat and two finish coats of paint.

RENEWAL PARTS

Orders for renewal or supply parts should be placed with the nearest Apparatus Sales Office of the General Electric Company. Specify the quantity required and give the catalog or drawing number along with part numbers whenever possible. Catalog numbers of the parts most likely to need replacing, such as the arcing contacts in load-tap-changing equipment, are listed in the applicable leaflets. If the required numbers are not available, describe the parts in detail. When requesting information or ordering parts for a particular transformer, always include the serial number appearing on the transformer nameplate.

Materials that are unaffected by Pyranol have been used in constructing Pyranol transformers and no substitutions should be made for these materials without the approval of the General Electric Company. Any renewal parts supplied will be manufactured from the same or similar materials as those used for new transformers. Successful operation of the renewal parts is contingent upon proper field assembly, the condition of the remaining parts, and a thorough drying cycle if moisture has entered the transformer.

WHEN YOU NEED SERVICE

If you need to repair, recondition, or rebuild any electric apparatus, a G-E Service Shop near you is available day or night, seven days a week, for work in the shop or on your premises. Latest factory methods and genuine G-E renewal parts are used to maintain the original performance of your G-E equipment. For full information about these services, contact the nearest Apparatus Sales Office or General Electric Service Shop.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

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Oil-Immersed Transformers

RATED 10,001 THRU 25,000 KVA

CONTENTS

	Page
INTRODUCTION	1
INSPECTION	1
HANDLING	3
STORAGE	3
SEALED TANK TRANSFORMERS	3
INSTALLATION	4
CONNECTIONS	6
MAINTENANCE	7
WHEN YOU NEED SERVICE	9

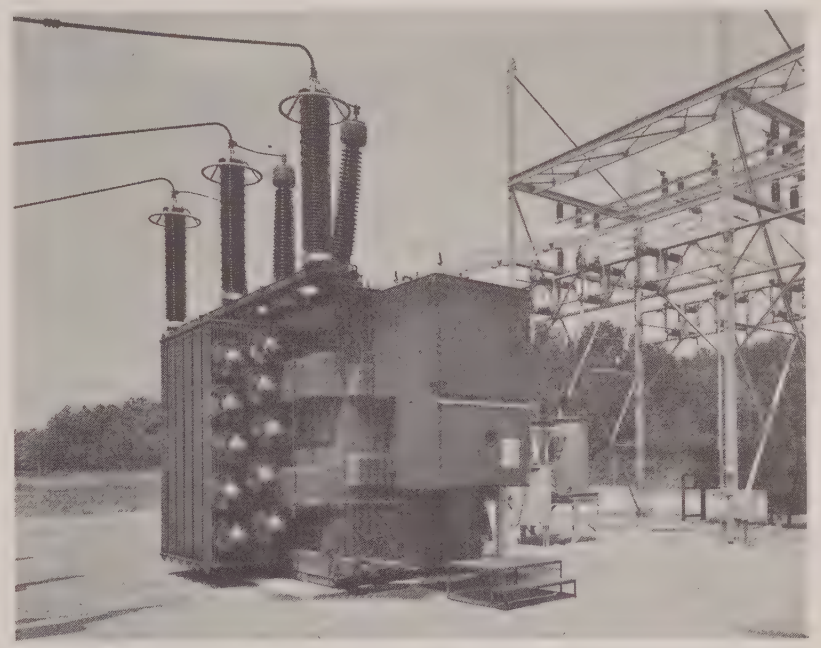

Fig. 1. Typical installation

INTRODUCTION

In order to reduce shipping weight and facilitate unloading and handling, the transformer insulating oil will normally be removed for shipment. The tank will then be filled to a slight positive pressure with dry nitrogen gas and the necessary oil will be shipped separately in drums or by tank car, depending upon the location. Before placing the transformer in service, it is to be oil filled under vacuum as described in subsequent paragraphs.

A number of items such as bushings, lightning arresters, radiators, etc., may also be removed in order to provide the required shipping clearances. These components are to be installed in accordance with the appropriate instructions furnished with the transformer and as shown on the transformer Outline drawing.

DRY NITROGEN GAS

The dry nitrogen gas referred to throughout these instructions can be obtained in cylinders containing 220 cu. ft. of gas at atmospheric pressure, compressed to 2000 psi at 70F. Orders for this gas should specify "Special *dry* nitrogen to General Electric designation D27A3A." This gas can be purchased from any of the following vendors: Air Products & Chemicals, Inc., Allentown, Pa.; National Cylinder Gas Div., Chemetron Corp., Chicago, Ill.; Linde Div., Union Carbide Corp., New York, N. Y.

The proper regulating valve should be obtained for introducing gas into the transformer. Before transferring any gas, invert the cylinder for 24 hours in an ambient temperature not lower than 20C. With the cylinder still inverted, open the valve for a few seconds to remove any moisture that might accidentally be present. Return the cylinder to an upright position for transferring the gas and discontinue its use when the pressure drops to 200 psi.

INSPECTION

The transformer and the boxes containing its supplies should be inspected immediately upon receipt. It is preferable to make the following inspection before the transformer is removed from the car. This will prevent the needless expenditure of time and money for unloading in the event conditions are found to exist which cannot be corrected at the installation site. The inspection will also tend to remove any doubt about the condition of the equipment as delivered by the carrier and provide an opportunity to file a damage claim should that become necessary.

EXTERNAL INSPECTION

Make an external examination of the transformer, its accessories, and hardware for obvious signs of damage or rough handling including a check for broken tie rods or anchor bolts, loose blocking, hairline cracks or seepage along the baseplate, etc. Check the materials received against the Shipping List and report any shortages to the nearest Apparatus Sales Office of the General Electric Company.

IMPACT RECORDER

The impact recorder shipped with the transformer is normally of the two-way type which simultaneously records shipping impacts in both the longitudinal and vertical directions on a single tape. The recorder uses a red-colored tape which is long enough to record for 16 days. It has a longitudinal scale divided into 5 zones on either side of the center line and an overlapping vertical scale along the left-hand margin. The vertical scale is divided into 10 narrow zones, reading from right to left.

The recorder should be opened upon

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC

arrival and its tape examined in accordance with the instructions provided inside the cover. A critical examination of the transformer should be made when the tape indicates that any of the following types of impacts have been sustained in transit:

1. Any longitudinal impacts in zone 3 or above.

2. Numerous longitudinal impacts in zone 2.

3. Vertical impacts in zone 5 or above for periods of 2 to 3 hours.

4. Vertical impacts in zones 3 and 4 for periods of 8 to 10 hours.

Sign and date the tape and *return it promptly along with the recorder.* Due to the limited supply of these recorders and the length of time required for their use on each shipment, it should be removed from the car as soon as it arrives and returned at once to the Medium Transformer Department, General Electric Company, Rome, Georgia, via Railway Express. Upon receipt at the factory, the tape will be analyzed in relation to the magnitude of the various impacts, the location of the transformer at the time the impacts occurred, the type of car employed, and any other factors affecting the shipment. Following evaluation, the tape will be available to the user in the event he has need of it in substantiating possible damage claims.

PRESSURE CHECK

The transformer should arrive at the destination with a slight positive gas pressure, except in cold weather when a partial vacuum may exist. If the pressure-vacuum gage indicates zero and there is no change in this reading with changes in temperature, a leak may have developed with the possibility of moisture having entered the transformer. When this is the case, the transformer should be checked as explained under "Leak Test" in order to locate the leak and evaluate its consequences.

INTERNAL INSPECTION

CAUTION—Before removing a manhole cover, shipping plate, or any other device, vent the transformer to atmospheric pressure. Do not enter the transformer until the gas space has been purged with fresh air or a suitable oxygen supply is available.

Laboratory tests indicate that once the cellulosic insulation in the transformer has been oil soaked, it absorbs moisture very slowly. If the following precautions are observed, the entrance of excessive moisture can be avoided and the small amount that does enter can readily be removed before oil filling by the application of a high vacuum. See "Oil Filling Under Vacuum." The transformer should not be opened when:

1. Rain or fog is present or threatening as this could allow free water to enter the unit.

2. The interior of the transformer is appreciably cooler than the outside ambient, especially in humid weather, as this condition can easily lead to moisture condensation within the transformer.

3. The temperature is consistently near or below freezing because at these temperatures removal of surface moisture by means of a high vacuum alone will be quite difficult, if not impossible.

Once the transformer has been exposed to the atmosphere, either during inspection or installation, the total time with covers removed should not be allowed to exceed 24 hours. When working on a transformer with the cover open, exercise care to see that no foreign matter is dropped into the tank. It is recommended that workmen tie wrenches and others tools to the tank before using them inside the transformer. A positive, dry nitrogen gas pressure should be established following inspection and each time the transformer is sealed at the end of a working day.

Note—If it is preferred to cover the core and coil assembly with oil before opening the unit for inspection or assembly, this filling can be done either with or without vacuum. Filling without vacuum at this time will require a subsequent draining and refilling under vacuum before placing the transformer in service. If a vacuum is to be used at this point, refer to the section entitled "Oil Filling Under Vacuum." Approximately 85% of the main tank oil will be required to cover the core and coils before breaking vacuum and the remainder of the oil can then be added after final assembly as indicated under "Final Filling."

Purging Shipping Gas

The nitrogen shipping gas can be purged from the transformer by any of the following means. It is not necessary to fill the transformer with oil before proceeding with one of these methods.

1. Natural Draft or Forced Air—Open two manhole covers, preferably at opposite ends of the tank, and either use a fan or allow normal breezes to purge the gas. With this procedure the nitrogen will be replaced with natural atmosphere and should, therefore, be used only when the relative humidity is low. After purging, the oxygen content should be at least 18%, as measured with a portable tester, before entering the tank.

2. Vacuum and Dry Air — Evacuate the transformer to about five inches (125 mm) of mercury and break the vacuum with *dry* air. A constant flow of dry air at about 0.5 psi on the gage at the gas bottle can then be introduced at the bottom of the tank and permitted to flow through the transformer while it is open. This will tend to prevent the entrance of moist air and afford the most pleasant working conditions inside the transformer. The dry air used in this method should have a maximum dew-point of —60F. Approximately 15 cylinders of air will be required to inspect a 10,000-gallon transformer in this manner.

3. Flush with Dry Air—Place a container under the main drain valve to catch any residual oil and open this valve. Remove at least two manhole covers and admit dry air through the drain valve until the oxygen content of the total mixture measures at least 18%. This method will, of course, require more dry air than method 2 and is more time consuming.

Examination

Inspect the top of the core, coils, and the underside of the cover for visual signs of moisture such as rust, condensation, etc. Check the steel wedges between the top core clamps and tank wall at each corner to determine if they are loose or if there has been any relative movement of the various parts. Look for signs of shipping damage such as broken lead supports, dislodged end insulation, loose nuts and bolts, etc. Examine all cable insulation for cracks or breaks and frayed or worn places which may have been caused by impacts or continuous vibration during shipment.

Core Ground Test

The transformer core steel is insulated from its clamping structure except at a single point at the top where a strap or cable connects it to ground. To be sure there are no other grounds, disconnect the core ground connection and make a 500 or 1000 volt insulation resistance measurement between the core strap or cable and ground. A reading of at least 25 megohms should be obtained.

Ground straps are slotted on the end to fit under a bolt which has been threaded into a nearby channel or angle. This joint can be opened by loosening the bolt and slipping the strap out from under it. Do not remove the bolt. In some cases a cable lead may be brought up from the core to a grounding block located on the main tank wall near a manhole. Occasionally a second lead will also be brought to this block to ground the clamping superstructure on a resiliently mounted core and coil assembly. This joint may be opened by removing the bolts which then remain captive in the cable blade.

Liquid Filled Shipments

The inspection procedure for transformers shipped liquid filled should follow as closely as possible that described for gas-filled units. In addition, dielectric tests should be run on the insulating liquid and the presence of any floating debris on the oil should also be noted.

In making the internal inspection a weighted sealed beam lamp of the pyrex glass type will aid in observing the interior of the unit through the insulating liquid. Enclose the lamp in fine mesh wire before lowering it into the tank to prevent scattering of the glass in case the lamp is accidentally broken. It is recommended that a lamp cord having synthetic insulation be used and that the lamp be immersed in the oil before being turned on.

A more thorough internal inspection can be made by lowering the oil to the top of the core. Care should be taken not to expose the windings and end insulation to the atmosphere unless the unit is to be completely drained and refilled under vacuum. (See "Oil Filling Under Vacuum.")

Resealing After Internal Inspection

As soon as the internal inspection has been completed, reseal the transformer and pressurize it to approximately 2 psi with dry air or dry nitrogen. This pressure should be maintained while moving the unit to the installation site and until it is reopened for final assembly. If there is to be a delay of more than a month before placing the unit in service, refer to the section entitled "Storage" for the procedures to be followed.

FINDINGS

If results of the inspection indicate that the transformer has arrived without damage and that no moisture has entered during transit, remove the unit from the car and proceed with the installation. However, if evidence of shipping damage is found and it is desired to file a claim against the transportation company, a representative of the carrier should be requested to inspect the transformer before it is unloaded from the car. The damage should also be reported to the General Electric Company through the nearest Apparatus Sales Office.

If there is reason to suspect that moisture is present, it may be necessary to dry the transformer. Questions concerning the need for drying as well as the methods to be used should be referred to the Apparatus Sales Office. These matters should be resolved before unloading since such factors as low winter temperatures, available power supplies, etc., may make it desirable to move the transformer to some other location for drying. If drying is required, the necessary facilities are available, and assembly will start within one month, it is recommended that the drying operation be deferred until the installation is completed and the transformer is ready for oil filling. If the transformer is to be stored for more than a month before installation, it should be dried by an approved method prior to storing.

Additional recommendations can be obtained through the Sales Office concerning such problems as possible moisture in the oil, for which more sensitive tests can be arranged, and possible core grounds, for which certain clearing procedures can be discussed.

HANDLING

The direction of shipment shown on the Outline drawing must be observed whenever the transformer is placed in transit. The unit should always be handled in the normal upright position unless specific recommendations for special handling are obtained from the General Electric Company. Junction boxes and other accessories can be removed when necessary to facilitate handling in restricted areas. Before moving a transformer from one site to another, remove any lightning arresters mounted on it.

LIFTING

Lugs are provided for lifting the complete transformer and where necessary, provisions are included for lifting the various parts. Since the main transformer lifting lugs are designed for vertical stress only, the lifting cables must be spaced apart by means of a lifting beam or spreader. A beam or spreader is not required when sling guides are provided on the transformer. Use lifting cables of the same length so that the transformer will be lifted evenly.

To prevent buckling of the tank walls when lifting the complete transformer, the cover must always be securely fastened in place. Location of the center of gravity and the approximate weight of the transformer are shown on the Outline drawing. The weight is also given on the nameplate.

JACKING, ROLLING, SKIDDING

Jack bosses are provided as shown on the transformer Outline drawing. Do not attempt to raise the transformer by placing jacks under the base, drain valves, pipe connections, or any other component. The unit can also be rolled or skidded along either axis by means of the pulling holes provided at the base. Use restraining cables when rolling downgrade.

STORAGE

It is advisable to completely assemble the transformer at its permanent location as soon as it is received even though the unit is to be stored for a period of several months or more before being placed in service. Transformers shipped liquid filled should be checked for proper oil level, resealed, and pressurized to 5 psi, using dry nitrogen gas.

In the case of transformers shipped gas filled, oil filling prior to storage is recommended as the best means of keeping moisture absorption at a minimum. See "Oil Filling Under Vacuum." Depending upon the circumstances, oil filled storage may be justifiable even though the transformer will have to be drained at a later date for movement to its final installation site. If preferred, transformers shipped gas filled may be stored in that condition by resealing after inspection and pressurizing to 5 psi with dry nitrogen. (If there is reason to suspect that moisture entered during inspection, it may be desirable to hold a 2 millimeter vacuum on the transformer for at least 4 hours before pressurizing for storage.)

Transformers equipped with automatic-gas-control equipment need not be pressurized to 5 psi. A slight positive pressure can be maintained on the tank for the duration of the storage period by installing the gas cylinder and placing the regulating system in operation as described in separate instructions furnished with that equipment. If desired, the low-pressure alarm switch can also be connected into an appropriate circuit.

Any parts which are not installed should be stored in a clean, dry place to avoid rusting and other damage. Shipping cartons and crates should be opened sufficiently to allow free circulation of air and extreme temperature changes should be avoided if possible. The transformer should be inspected at periodic intervals to insure that it remains in satisfactory condition. Check the pressure-vacuum gage to see that a positive pressure is being maintained and examine the various accessories and controls for evidence of moisture condensation, etc.

Before completing the installation or placing the transformer in service, it should be checked for dryness. This can be done by checking the dielectric strength and moisture content of the oil in liquid-filled units or by making power factor measurements (see GEI-65070) after the oil filling of a unit stored gas filled. Questions concerning the need for drying and methods to be used should be referred to the Apparatus Sales Office.

SEALED-TANK TRANSFORMERS

Sealed-tank transformers are provided with a gas space above the insulating liquid. This space serves to

cushion the tank against changes in pressure created by expansion and contraction of the liquid. Under normal operating conditions the space remains sealed from the atmosphere, thus protecting the insulating liquid against contamination and maintaining its dielectric strength at a high value over a long period of time. When the space available in the main tank is limited, additional space is sometimes provided by piping down to the channel braces or, occasionally, by the use of a separate expansion tank.

INSTALLATION

Provide a strong, level foundation, preferably of reinforced concrete. For transformers having flanged wheels, rails must also be provided. When key interlocks are used with disconnect switches, circuit breakers, tap changers, etc., make sure all components using the same key are installed in the same circuit.

Select a location where air can circulate freely. If the transformer is to be installed in a compartment or vault, provide adequate ventilation to avoid overheating. At high altitudes, decreased air density reduces transformer cooling efficiency and lowers bushing arc-over voltages. If transformers are to be moved to an elevation above 3,300 feet, consult the nearest Apparatus Sales Office of the General Electric Company relative to their suitability for operation at the higher altitudes. Transformer finishes and components are designed for normal life in a non-corrosive atmosphere. Atmospheres which include corrosive agents may require additional protective measures.

Temporary shipping parts are marked red and must be removed before placing the transformer in service. These may include both internal and external parts such as braces, bushing terminal block supports, the tape used to secure terminal board links, covers, breathers, or pipe caps and plugs. Parts removed for shipment are identified by appropriately marked copies of the shipping list and are to be installed as shown on the transformer Outline drawing. Components to be installed within the transformers should be kept at least as warm as the surrounding air to avoid condensation. (Note venting precaution under "Internal Inspection.")

Complete information on the accessories can be found in the leaflets pertaining to those devices. The danger of breaking bushings can be minimized by installing them last. For wiring details, refer to the transformer Connection Diagram. When installing breathers, be sure they are turned down to prevent entrance of moisture. Use G-E Compound A15A11A or Teflon tape to seal threaded joints. When installing radiators, keep the valves closed until ready to complete the liquid filling or to lower the liquid level for an internal inspection. When a radiator has been filled, do not close both top and bottom valves at the same time unless the radiator is to be *immediately removed.* Damaging hydrostatic pressures can be generated by temperature changes when both valves are closed.

OIL FILLING UNDER VACUUM

This transformer is to be oil filled under vacuum initially and at any time thereafter that the coils or end insulation are exposed to the atmosphere. Detailed information on sampling, testing, and handling procedures for insulating oil is contained in separate instructions. When transferring the liquid to the transformer, it should be passed through an approved filter system to remove any undetected moisture or sediment. The filter system must be tight to prevent air from being drawn into the pumping equipment on the intake side.

Once oil filling has started it should be continuous. If work is to be done inside the transformer after filling or if an inspection is to be made, discontinue pumping when approximately 85% of the main tank oil has been added (see transformer nameplate).

WARNING — Static charges can be developed when transformer oil flows in pipes, hoses, and tanks. Oil leaving a filter press may be charged to over fifty thousand volts. To accelerate dissipation of the charge in the oil, ground the filter press, the piping, the tank, and all bushings or the winding leads during oil flow into any tank. Conduction through oil is slow, therefore, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped.

Arcs can occur from the free surface of the charged oil even though the previous grounding precautions have been taken. Therefore, explosive gas mixtures should be removed from all containers into which oil is flowing.

Connections

Connect the oil line to the top filter press valve on the transformer and install a 100 psi pressure gage next to the valve as shown in Fig. 2. A high reading gage is suggested to prevent damage should the oil filter be started with the valve shut. Introducing oil at the top of the transformer serves to deaerate it as it falls and also aids in the removal of any free air entering through the oil handling equipment.

A high efficiency vacuum pump with a 10 micron capability when blanked off and at least 140 cfm capacity will be adequate for filling most transformers. If a smaller pump is used, it may prolong the filling time. Connect the pump to the two-inch pipe nipple provided on the transformer cover using a vacuum

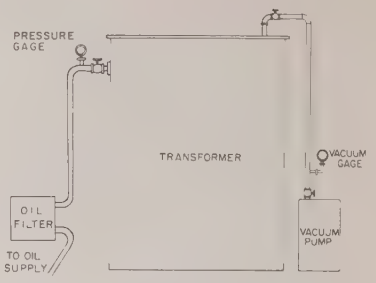

Fig. 2. Filling under vacuum

line of at least two inches in diameter and preferably larger in order to hasten evacuation. Install a shutoff valve at the cover connection and keep the piping as short as possible.

Precautions

1. The high vacuum required for oil filling should not be drawn on a partially filled transformer if there is a possibility that its oil may contain dissolved gases. Vacuums in this order of magnitude will tend to release these gases and the resulting bubbles can easily become trapped, forming voids in the insulation system. If the core and coils are already covered, filling should be completed by the appropriate method as described under "Final Filling." Otherwise, the unit should be drained and then refilled under vacuum.

2. All leaks must be detected and repaired before the filling process is started in order to prevent the entrance of air or moisture as the vacuum is drawn. See "Leak Test."

3. Make sure valves to the radiators, pump(s), fault-pressure relay, etc., are open.

4. Do not operate the load-tap-changing (LTC) equipment when the main tank is under vacuum as the mechanism may bind at this time.

5. Do not apply any voltage to the windings or current transformers while the unit is under vacuum as this may damage the insulation.

6. Oil vapors can present an explosion hazard in the LTC switch compartment and, therefore, test voltages should not be applied to the mechanism except when the door is open or the compartment is oil filled.

7. Before filling a sealed-tank transformer under vacuum, remove the pressure-vacuum bleeder and replace it with a pipe plug.

8. Automatic-gas-control equipment must have the gas regulator and supervisory equipment protected by closing the feeder valve between the sump compartment and the transformer and opening the sump drain valve.

9. Gas-oil-seal transformers must

have the expansion tank isolated by removing the ½" pipe plug from the block where the piping enters the transformer tank and inserting a ⅛" pipe plug into the opening provided for sealing.

10. Oil-filled compartments, such as the tap selector portion of load-tap-changer equipment, disconnect switches, junction boxes, etc., must not be subjected to more than a 5 psi vacuum.

11. Conservator-type transformers require a slightly different filling procedure. See "Conservator-Type Transformers."

Filling

Transformers which have been opened for inspection should have any possible accumulation of surface moisture removed before filling by drawing a vacuum of 2 millimeters absolute pressure and holding for four hours plus a period of time equal to the exposure time (which should not have exceeded 24 hours as indicated under "Internal Inspection"). Keep the vacuum pump running during the holding period in order to maintain the required vacuum. CAUTION—The vacuum should not be held while it is raining nor at any other time when water or humid air might be drawn into the transformer through leaks. Also note that removal of moisture in this manner will be practically impossible at temperatures near or below freezing.

If the core and coil assembly has not been exposed to the atmosphere and the transformer seal has been maintained without leaks, satisfactory oil filling can be accomplished by drawing a 25 mm vacuum and holding for a period of 4 hours prior to and during the filling.

After maintaining vacuum for the required holding period, open the top filter press valve on the transformer and start the filter press equipment. Maintain the vacuum on the transformer while filling and limit the rate of oil flow to a maximum of 25 gpm. In order to avoid the possibility of drawing air into the system, the top filter press valve should be adjusted to maintain a positive pressure on the oil line. If difficulty is experienced in holding vacuum during the oil filling, further throttling of the oil flow may be necessary.

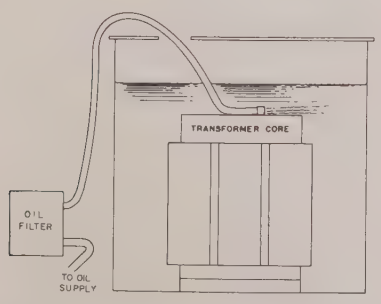

Fig. 3. Final filling through a manhole

Continue filling until the liquid level gage begins to move and then break the vacuum by admitting dry nitrogen gas. After filling, the transformer should be allowed to stand for at least 24 hours and preferably longer, before energizing to permit complete absorption of possible entrapped gas bubbles. Oil pumps should be operated when provided. CAUTION—When a transformer is stored gas filled, the residual oil will gradually drain out of the paper insulation. To assure proper oil impregnation of the insulation in these transformers, allow at least 96 hours after filling before energizing.

Conservator-Type Transformers

When vacuum filling conservator-type transformers proceed as follows:

1. Connect the oil line to the pipe nipple provided on the cover of the transformer.

2. Avoid drawing a vacuum on the conservator tank by closing its shut-off valve (or by installing it later).

3. Vacuum fill with 85% of the main tank oil.

4. Add the remainder of the main tank oil through a manhole as explained under "Final Filling."

5. Seal the unit and complete the filling through the conservator tank as explained in separate instructions on conservator-type transformers.

Final Filling

Final filling under full vacuum is permissible providing it is done before significant reabsorption of air has occurred in the oil. If no more than 48 hours has elapsed since the initial filling was discontinued and the circulating pump has not been run, the remaining oil can be added under vacuum in the same manner as the initial filling.

Otherwise, the final filling should be done through a manhole by laying the hose on top of the core and directing the oil flow parallel to and along the top of the core as shown in Fig. 3. Filling in this manner minimizes aeration of the oil and the possibility of entrapping air in the insulation or coils below the level of the initial oil filling. Adjust the liquid level until the distance from the oil to the top of the manhole flange agrees with that called for on the nameplate (with the necessary correction when the oil temperature differs from 25C).

GASKETS

Gaskets used to maintain the transformer seal have been selected for their ability to resist deterioration by the insulating liquid and to avoid contamination of the liquid. Gaskets made of nitrile (Buna N) and fluorinated rubber (Viton, Fluorel, etc.) are used on oil-filled transformers. Gaskets provided with the transformer or as replacement items are especially compounded to G-E specifications and substitution of improper materials for these gaskets may result in unsatisfactory joint life.

Replacement or spare gaskets can be purchased to size through the nearest Apparatus Sales Office of the General Electric Company. Identify the parts wanted as explained under "Renewal Parts." If an extended storage period is anticipated it is recommended that spare gaskets be placed in a clean, dark place away from high temperatures.

All of the gaskets used to maintain the transformer seal can be reused many times unless damaged. Before installing a new gasket or replacing an old one, thoroughly clean the gasket surfaces. Although in most cases no sticker is required, the compound furnished with the gaskets may be used if desired. All gaskets are to be installed with their widest dimension next to the gasket surface and in the case of scarfed gaskets made from strip material it may be necessary to use a sticker to hold them down. Square gaskets with scarfed joints should be installed with the scarf laying flat, in a position where the compression forces will clamp the joint together, rather than on edge where clamping tends to open the joint and produce leaks. Compress the gasket approximately one-third, or to the stops when provided in either the mating parts or in the gasket itself. Gaskets are compressed to the stops when there is a noticeable increase in the torque required to tighten the bolts.

A leak test is recommended following the opening and closing of any gasketed joint affecting the transformer seal.

Weatherproof Joints

If a removable, air-filled compartment is shipped separately, a length of sponge rubber gasket is furnished for the purpose of weatherproofing the joint between the compartment and the transformer. Install this gasket just outside the mounting studs or bolt holes and for the best weather-resistant joint allow the piece across the top to overlap the two side pieces.

To install a sponge rubber gasket, clean the surface on which it is to be mounted and apply a thin coat of the adhesive furnished to both the metal and the gasket. (*Do not* apply adhesive to the edges or outside surface of the

gasket.) Allow the adhesive to dry until it is no longer tacky and then press the gasket against the metal with enough pressure to make a good contact.

When a retaining strip is provided the gasket should be assembled with its inner edge in contact with the strip. Tighten the gasket down to this stop or in the absence of a stop, compress it to approximately ½ size.

CHECK LIST

The following list can be used as a general guide for inspecting, checking, and testing the various accessories and other features of the transformer, when provided. For detailed information, refer to the applicable instructions.

1. Make certain all parts shipped separately have been assembled.

2. Make an internal inspection:

   A. For correct terminal board connections as shown on the nameplate.

   B. To see that all terminal nuts and connecting links are tight, including the load-tap-changer terminal board.

   C. For obvious lead clearances.

3. Check to see that all temporary shipping parts (items painted red) have been removed.

4. Be sure all radiator, pump, and manifold valves are bolted in the OPEN position.

5. It is recommended that a low voltage ratio test be made on each tap changer and LTC position.

6. See that the tap changer wedge seats itself properly in each tap position. The tap changer drive will be at the center of a high torque region when the wedge is in an operating position.

7. Check the gas system on transformers provided with automatic gas control equipment.

8. Inspect accessories and control equipment and check wiring and alarm circuits.

9. Check the fans for proper rotation and see that their number, type, and location agree with the transformer Outline drawing.

10. Check operation of pumps (the liquid flow gage will not indicate oil flow if pump rotation is incorrect.)

11. Inspect load-tap-changing equipment as follows:

   A. Open the compartments and check for loose or damaged parts, including cracked porcelains, etc.

   B. Make sure the breathers have been installed on the liquid-filled switch compartment.

   C. Operate through all positions by hand and check for binding.

   D. Operate through all positions by motor and check the limit switches, position indicator, operation counter, automatic features, and dynamic braking (when furnished).

12. Make sure all gasketed parts having grooves or stops are drawn up metal to metal and tighten all valve stem nuts.

13. Check the oil level in the main tank (see "Final Filling") and in the various separate compartments such as junction boxes, throats, disconnect switches, potential devices, etc. Also make final dielectric test of the oil.

14. Power factor measurements are recommended as a method of obtaining a more meaningful indication of the condition of the entire insulation system in the transformer. In general, oil-filled transformers should have a power factor of 2 percent or less (corrected to 20C). Those having load-tap-changing equipment may be slightly higher but figures much in excess of this value indicate the presence of moisture or other contaminants and should be questioned. Refer to instructions GEI-65070 for details of the procedures to use, calculations to make, etc.

15. Make a final leak test before placing the transformer in service.

LEAK TESTS

Inspect the entire transformer for evidence of leaks and make the following pressure test. Introduce dry nitrogen through the pressure test valve until the tank pressure reaches a value just slightly less than the maximum operating pressure shown on the nameplate. Seal the transformer at this pressure and make an examination for leaks. Gas leaks can be located by applying a liquid-soap solution to all gasketed joints, pipe fittings, etc. To detect oil leaks, the unit should be examined over a period of about 12 hours.

ESTABLISHING THE SEAL

Sealed tank transformers should be pressurized to 3 psi with dry nitrogen gas. Conservator, gas-oil-seal, and automatic - gas - control transformers have slightly varying sealing procedures which are described in separate instructions furnished with that equipment. Flushing of the gas space is not considered necessary since the oxygen in the air combines chemically with the oil during the first few weeks of operation.

However, if it is the user's practice to purge the gas space, this can be done by removing the pipe plug from the vent hole on the manhole cover (or main tank cover) and admitting dry nitrogen gas through the transformer pressure test valve. Allow the nitrogen to flow until the escaping gas tests five per cent oxygen or less. After 24 hours, analyze the gas again and repeat the flushing operation if necessary. No more than three flushings should be required.

PAINT FINISH

Use an oil solvent to thoroughly remove any oil on the outside of the tank or on gaskets. This will avoid the false impression of leaks in the future. When the installation has been completed, clean all damaged paint areas and, using the touch-up paint provided, apply one primer coat and two finish coats. Allow at least 16 hours drying time between coats. Examine the paint finish at periodic intervals for signs of deterioration and clean and repaint as required.

CONNECTIONS

Transformers having internal terminal boards are normally shipped connected for the highest rated voltage. When shipped otherwise, a tag fastened to the nameplate will indicate the connections that have been made. Before applying voltage to a transformer, see that the windings are connected for the desired voltage. Make no connections except those authorized by the nameplate.

TANK GROUNDING

Ground the tank permanently and effectively by means of the ground pads provided at the base of the tank. A good, permanent, low-resistance ground is essential for adequate protection. A poor ground may be worse than none at all as it gives a sense of false security to those working around the equipment and may result in serious injury or damage to the transformer.

SYSTEM GROUNDING

Transformers having reduced insulation at the neutral end of a winding or in a neutral bushing can be operated with the neutral either solidly grounded or grounded through an impedance which will limit the low frequency and impulse voltages from neutral to ground to values consistent with the insulation levels shown on the nameplate.

LINE AND LOAD CONNECTIONS

Make line and load connections tight and see that there are no strains on the terminals which will cause the joints to become loose. Provide sufficient flexibility in the leads to prevent porcelain breakage caused by expansion and contraction. The bushings will support a considerable weight of conductor, but long spans of unsupported conductor,

especially if outdoors, should be avoided. Refer to the bushing instructions for more detailed information.

Single-phase transformers suitable for Y operation on either the high- or the low-voltage side may be so connected on either side, but not simultaneously on both sides unless precautions are taken to suppress third harmonic voltage.

LIGHTNING PROTECTION

Protect every transformer from lightning disturbances by some form of direct stroke protection and by approved lightning arresters that are installed as near as possible to the transformer and are directly and effectively grounded. The incoming line should be brought to the arrester first and then to the transformer bushing.

MAINTENANCE

Certain items on the transformer should be inspected at regular intervals. The actual frequency of inspection should be adjusted for each application according to the importance of continuity of service and as experience dictates. Refer to the instructions pertaining to a particular device for detailed information on maintenance or testing of that item.

ITEMS TO INSPECT

- Automatic Gas-Control Equipment
  - Gas cylinder content
  - Low-pressure alarm circuit
  - Transformer gas-pressure gage
- Control Circuits and Equipment
- Fans
- Gas Analysis
- Insulating Liquid (See GEI-65070)
  - Level
- Load Current and Voltage
- Load-Tap-Changer Equipment
- Pressure Gage
- Temperature
  - Ambient
  - Liquid
  - Winding

EXTERNAL CLEANING

The bushing porcelains should be inspected at regular intervals and kept reasonably free from dust and dirt. In locations where abnormal conditions prevail, such as sand storms, salt deposits, cement dust, acid fumes, etc., a special hazard may exist, and the bushings should be cleaned regularly to avoid accumulations on the external surface which may result in flashover.

Keep the heat radiating surfaces of the transformer clean. Transformers, especially those near the seacoast, should be kept painted to prevent corroding or rusting of metal parts. Periodically inspect the small screened openings in the breathers and/or pressure-vacuum bleeder to be sure they are clean and operating.

CONTROL CIRCUITS AND EQUIPMENT

Inspect regularly for the following:

- Control-circuit voltage
- Collections of dirt or gum
- Excess heating of parts—evidenced by discoloration of metal parts, charred insulation, or odor
- Freedom of moving parts (no binding or sticking)
- Corrosion of metal parts
- Remaining wear allowance on contacts
- Excess slam on pickup
- Proper contact pressure
- Loose connections
- Condition of flexible shunts
- Worn or broken mechanical parts
- Excessive arcing in opening circuits
- Excessive noise in a-c magnets
- Evidence of dripping water or liquids falling on controls
- Operation—including proper functioning of timing devices, etc.

Grease, oil or sticky dirt may be removed with a lint-free cloth moistened in a nonflammable cleaning fluid. Do not soak the parts with the cleaner; but use just enough to loosen grease or dirt so that it can be wiped off. For cleaning small parts, a small paint brush dipped into the cleaning solution is good for getting into corners and crevices.

COMBUSTIBLE GAS ANALYSIS

It is recommended that the transformer gas space be sampled for combustible gases at regular intervals using either a portable gas analyzer or a permanent monitoring device. If at any time, the combustible gas content is found to exceed 1% by volume, purge the gas space with dry nitrogen and then recheck to see that the gas content levels off at one tenth or less of the original value. If the combustible gas content should continue to rise after purging, possible internal difficulties are indicated and an immediate investigation should be made to determine the cause of the gas. A gas analysis will reveal which types of gases are present and their relative percentages, thus providing a clue as to the probable source of trouble. For instance, the combinations of gases produced by arcing in oil will be different from those produced by overheating of a bare conductor or the decomposition of cellulosic materials.

If suitable testing facilities are not available, arrangements can be made through the nearest Apparatus Sales Office of the General Electric Company for a detailed factory analysis of the gas. An evacuated bottle will then be provided for use in obtaining a gas sample from the transformer. When returning this sample, furnish a brief history of the transformer including whether or not any welding repairs have been made with oil in the unit. This information is essential to the interpretation of the results of the gas analysis! Upon completion of the analysis, suggestions on where to look for the source of the difficulty and recommendations on the future operation of the transformer can be made. An oral report will be given within 24 hours following receipt of the sample at the factory in Rome, Georgia and a written report setting forth the elements of the oral report will follow in a few days.

LOAD RECORDS

Records of load and voltage on the transformer should be checked occasionally to see that the transformer is operating within the prescribed limits and is being used efficiently. When tapped windings are used, over-excitation and excessive core loss can result from improper tap connections.

TEMPERATURE RECORDS

Changes in indicated temperatures are often the only means by which the operator can detect the occurrence of abnormal conditions within the transformer. Operating temperatures, therefore, are important from this standpoint and should be carefully recorded and examined as often as practical, along with coincident records of ambient temperature, load and excitation. Examination of such records will enable the operator to protect the transformer from extended periods of abnormal operating temperatures which may affect its life expectancy. If a temperature is indicated which is more than 5 C higher than attained under the same conditions of load, excitation, and ambient temperature when the transformer was first placed in service, notify the nearest Apparatus Sales Office of the General Electric Company.

OPERATING TEMPERATURE

The operating temperature of the transformer should not exceed values given in the NEMA Standards for Transformers, Publication No. TR 1-1968. Temperatures above those recommended will result in accelerated deterioration of the liquid and may or may not affect the insulation, depending upon the hottest-spot temperature of the windings.

The top-liquid temperature alone is NOT recommended for indicating safe overload conditions within the apparatus. Hottest-spot temperature readings will give a more accurate indication of load conditions within the equipment, because the hottest-spot temperature rise over the top-liquid temperature varies widely for different methods of cooling and different loads. For con-

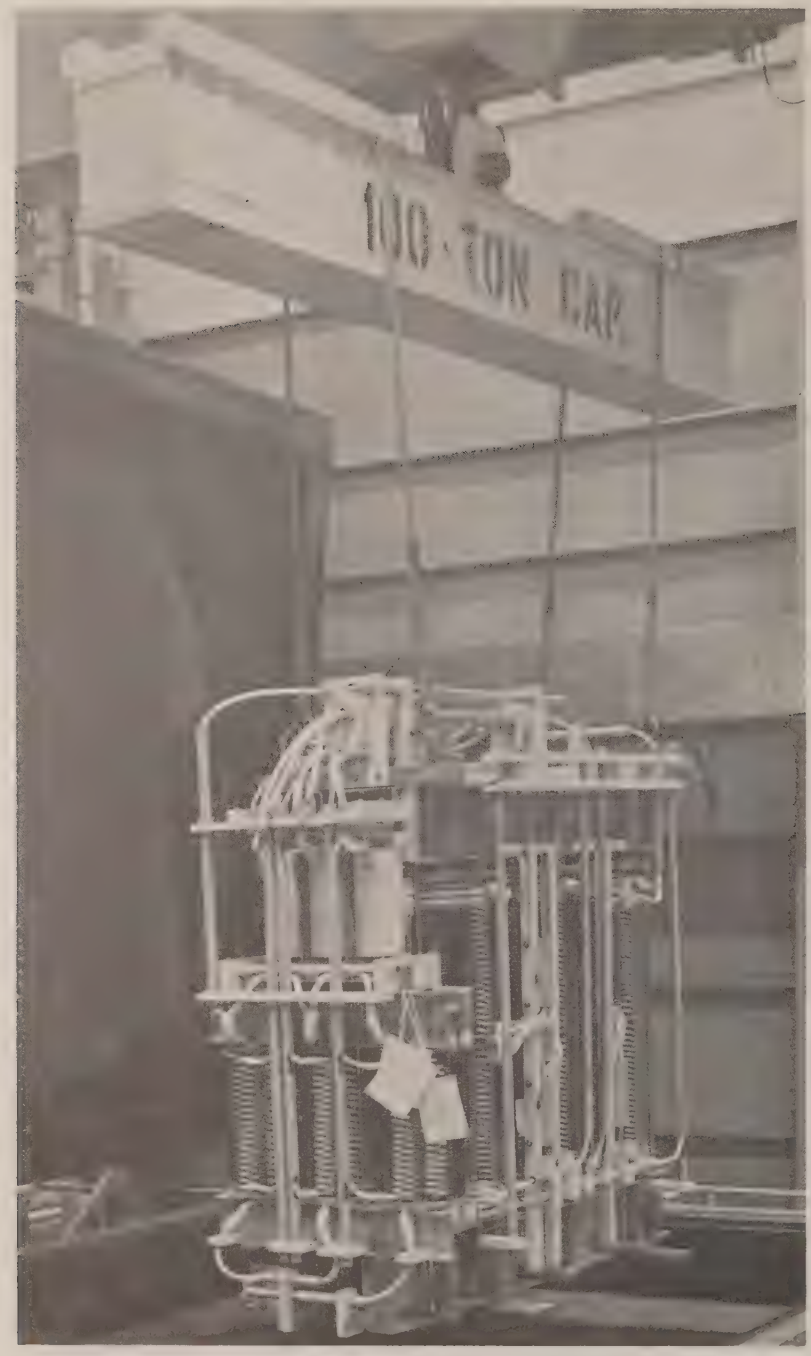

Fig. 4. Transformer core and coils showing use of lifting beam

tinuous overload operation of the transformer, refer to the NEMA Loading Guide, Publication No. TR 1-1968 Part 90. If there is doubt about a specific piece of equipment, contact the nearest Apparatus Sales Office of the General Electric Company for advice.

INTERNAL MAINTENANCE

Under normal operating conditions, internal inspections should not be necessary except when a need is indicated by laboratory analysis of samples of the insulating liquid. If laboratory tests show signs of sludging in an oil-filled transformer, the internal parts should be thoroughly cleaned. Untanking is usually necessary to remove the sludge in the windings. Cleaning may be done by forcing oil under pressure from a nozzle onto the internal parts. Great care should be exercised in order not to damage any insulating material. Recondition or replace the old oil, referring to the applicable leaflets. Severe cases of sludging should be referred to the nearest Apparatus Sales Office of the General Electric Company for recommendations.

Untanking

If it should ever become necessary to untank the core and coils, disconnect any wiring from cover outlets and remove any parts which are connected between the cover and the sides of the tank. If the transformer has a welded cover, remove the weld bead as explained under "Removing and Rewelding Covers" before opening the unit. Drain the insulating liquid and remove or disconnect the bushings, current transformer secondaries, winding-temperature devices, liquid-level gage, and any other parts which might get damaged or interfere with removal of the core and coils. Refer to the instructions on wedge-type tap changers and remove the tap-changer operating mechanism, making sure that it is first set on Position 1.

If the transformer is provided with load-tap-changing equipment, disconnect all leads from the windings and reactor to the LTC terminal board. Make sure all leads are tagged in order to aid in proper reassembly. *Some transformer tanks may be unstable if the core and coils are removed from the tank and the load-tap-changer equipment is left in place.* It is recommended that the stability of the tank be checked as the core and coils are lifted and that blocking be added under the LTC equipment if required.

The steel wedges or anchor blocks between the top core clamps and tank wall must be removed before the core and coils can be taken out. Carefully lift the core and coils out of the tank, using a lifting beam or spreader (See Fig. 4) when needed to keep slings from interfering with the superstructure or when a series transformer is mounted on the end of the core and coil assembly. The untanking height is shown on the transformer Outline drawing. Since the clearance between the core and coils and the tank wall is usually small, exercise care to prevent damage to parts such as pressboard casings and lead supports.

Retanking

When replacing the core and coils, follow the procedure outlined above in reverse order. Note that locating pins are welded to the base of the transformer tank to prevent the core and coils from shifting. The holes provided in the cross-bars or angles under the bottom core clamps must positively fit over these locating pins. After the trans-

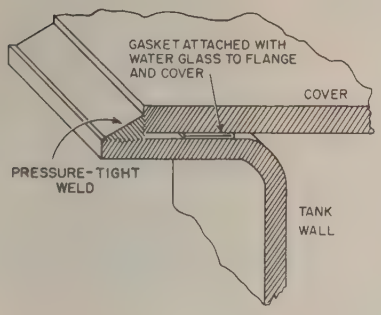

Fig. 5. Welded cover and gasket

former is completely reassembled, it may be necessary to dry the unit. For information on how to conduct a drying run, refer to the instructions on transformer drying. Questions on the necessity of drying a particular transformer should be referred to the nearest Apparatus Sales Office of the General Electric Company.

REMOVING AND REWELDING COVERS

Welded covers can be removed by chipping out the weld bead with diamond-point chisels and a pneumatic hammer or by the oxygen gouging method. The latter method is considerably faster and is recommended for all welds of 5/16" and over where adequate precautions can be taken for the fire hazard which exists with oxyacetylene cutting operations.

When removing the weld bead, the cover should be clamped to the tank flange to hold it in place and prevent chips or welding slag from entering the transformer. Protect all openings against the entrance of foreign matter. Before oxygen gouging on oil-filled transformers, thoroughly flush out the air space inside the tank with dry nitgoren or carbon dioxide gas and maintain a small flow of the gas during the gouging operation.

The entire weld may be removed in one pass, providing care is taken to avoid deep gouging of the edge of the cover or tank flange. The joint should be ground or chipped clean for rewelding before the cover is removed. Oxyacetylene cutting torch equipment is necessary with gouging tips similar to Air Reduction Style No. 183. For best performance of the gouging operation, a cutting torch similar to Airco Series 3000 having a graduated control of the high-pressure oxygen flow is recommended. Tip sizes and gas pressures recommended for various fillet weld sizes are as follows:

Fillet Weld Size	Tip Size	Oxygen Pressure	Acetylene Pressure
5/16-in.	No. 8	60 psi	8 psi
3/8 and 7/16-in.	No. 10	70 psi	9 psi
1/2-in. and up	No. 12	75 psi	9 psi

Rewelding the Cover

Before replacing the cover, remove all traces of dirt, grease, and oil from the areas to be welded. Cement a gasket to the tank flange or cover by applying a coat of water glass (sodium silicate) to both surfaces. The gasket should consist of a piece of 3/8-inch loose-twist glass or asbestos roving or a strip of 1/16 x 1½-inch dry asbestos folded to make it ¾-inch wide and should be located approximately ½-inch from the outer edge of the cover. See Fig. 5. To prevent spatter from entering the transformer during rewelding, compress this gasket by clamping the cover against its mounting flange and seal off all other external openings in the tank. Thoroughly flush out the air space with dry nitrogen and maintain a small flow of gas during the welding operation.

The arc welding process, using 3/16- or ¼-inch diameter electrodes, is recommended for rewelding the cover. The fillet should be built up with a series of passes to a thickness comparable to that of the original weld. In order to make a pressure tight joint, slag and spatter should be completely removed before each succeeding pass and at each point where the arc is interrupted.

When the welding has been completed, remove all scale and pressure test the joint as explained under "Leak Test." After a satisfactory test, clean the weld and adjacent surfaces and apply one priming coat and two finish coats of paint.

RENEWAL PARTS

Orders for renewal or supply parts should be placed with the nearest Apparatus Sales Office of the General Electric Company. Specify the quantity required and give the catalog or drawing number along with part numbers whenever possible. Catalog numbers of the parts most likely to need replacing, such as the arcing contacts in load-tap-changing equipment, are listed in the applicable leaflets. If the required numbers are not available, describe the parts in detail. When requesting information or ordering parts for a particular transformer, always include the serial number appearing on the transformer nameplate.

Any renewal parts supplied will be manufactured from the same or similar materials as those used for new transformers. Successful operation of the renewal parts is contingent upon proper field assembly, the condition of the remaining parts, and a thorough drying cycle if moisture has entered the transformer.

WHEN YOU NEED SERVICE

If you need to repair, recondition, or rebuild any electric appartus, a G-E Service Shop near you is available day or night, seven days a week, for work in the shop or on your premises. Latest factory methods and genuine G-E renewal parts are used to maintain the original performance of your G-E equipment. For full information about these services, contact the nearest Apparatus Sales Office or General Electric Service Shop.

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GENERAL ELECTRIC COMPANY
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MEDIUM TRANSFORMERS

AUTOMATIC GAS-CONTROL TRANSFORMERS

INTRODUCTION

The automatic gas-control equipment maintains an atmosphere of dry nitrogen under a slight pressure between the top oil surface and the transformer cover. This isolates the oil in the transformer from the outside air preventing oxygen, moisture and other contaminants from being absorbed. The nitrogen is supplied from a gas cylinder and is admitted to the transformer through a three-stage automatic gas regulator.

The transformer gas space is sufficiently large to allow for normal expansion and contraction of the oil. An automatic bleeder is provided to relieve any excessive pressures which may occur as a result of seasonal high temperatures or heavy load conditions. As lower temperatures are encountered and the pressure drops off, the gas regulator will automatically add gas to maintain a positive pressure.

The gas cylinder, regulator and supervisory equipment are mounted in a weatherproof cabinet attached to the transformer. See Fig. 1. During shipment the gas cylinder and regulator are removed and when necessary, the cabinet itself may also be removed.

Fig. 1. Gas control cabinet with accessories

DESCRIPTION

The automatic control equipment, shown in Fig. 2, consists of a three-stage gas regulator, sump, gages, automatic bleeder and a transformer low-pressure alarm switch. Alarms for transformer high-pressure and cylinder low-pressure can also be furnished upon request.

GAS CYLINDER AND VALVE

The nitrogen cylinder high-pressure valve has a double-seat construction as shown in Fig. 3. *To prevent gas leakage past the valve stem, the valve must be either tightly closed against the main valve seat or fully opened against the back seat.* In the open position, section B is held tight against section A by the screw-driver action

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC

of the valve. A relief disk is provided on the side of this high-pressure valve. If for any reason the gas pressure in the cylinder should increase to dangerous proportions, this disk will rupture and allow the gas to escape to the atmosphere.

GAS REGULATOR

The automatic gas regulator, Fig. 2A, is a three-stage device which serves to reduce the high pressure of the gas cylinder to a suitable value for application in the transformer tank. The first two stages of the regulator are set to deliver gas at 65 and 11 psi respectively, with a relief value located between the two stages. The third stage is set to admit gas to the transformer when the pressure in the tank drops to 0.30 psi and will automatically shut itself off when the pressure builds up to 0.55 psi. *Do not change any of these settings!*

Cylinder-Pressure Gage

The cylinder-pressure gage (1) indicates the nitrogen pressure in the gas cylinder. If desired, the gage can be supplied with alarm contacts to indicate low cylinder pressure. The contacts have an a-c rating of 10 amps at 115 volts or 5 amps at 230 volts and, unless otherwise specified, will be set to close when the pressure drops below 200 psi.

SUPERVISORY ASSEMBLY

The supervisory assembly, Fig. 2B, consists of sump (10), valves (6 and 8), transformer pressure gage (7), transformer low-pressure alarm switch (9), bleeder (11), and when requested, a transformer high-pressure alarm switch (not shown).

Sump and Valves

A sump compartment is provided to prevent the oil vapor, which condenses in the gas piping, from entering the regulating equipment. Valve (8) is for use in draining the sump at regular intervals and valve (6) is furnished for the purpose of maintaining the transformer seal while gas cylinders are being changed and for making leak test.

Transformer Pressure Gage

This gage indicates the pressure in the transformer gas space.

Transformer Low-Pressure Alarm Switch

Transformer low-pressure alarm contacts are provided by a self-resetting mercury switch (9). See Fig. 4. The contacts have an a-c rating of 10 amps at 115 volts or 5 amps at 230 volts and unless otherwise specified, will be set to close at 4 ounces per square inch and to reopen at 6 ounces per square inch. A nameplate on the device indicates its operating pressures. Do not allow the leads of the mercury switch to come in contact with anything that might impede operation of the switch.

Bleeder

Bleeder (11) automatically releases gas to the atmosphere whenever the pressure within the transformer builds up to the maximum operating pressure (as indicated on the transformer nameplate and the knurled screw cap of the bleeder).

Transformer High-Pressure Alarm Switch

When transformer high-pressure alarm contacts are requested, a bellows-operated, snap-action switch is provided which closes its contacts when the tank pressure becomes abnormally high. The contacts have an a-c rating of 10 amps at 115 volts or 5 amps at 230 volts and unless otherwise specified, are set to close at 1.25 psi above the maximum tank operating pressure.

INSTALLATION

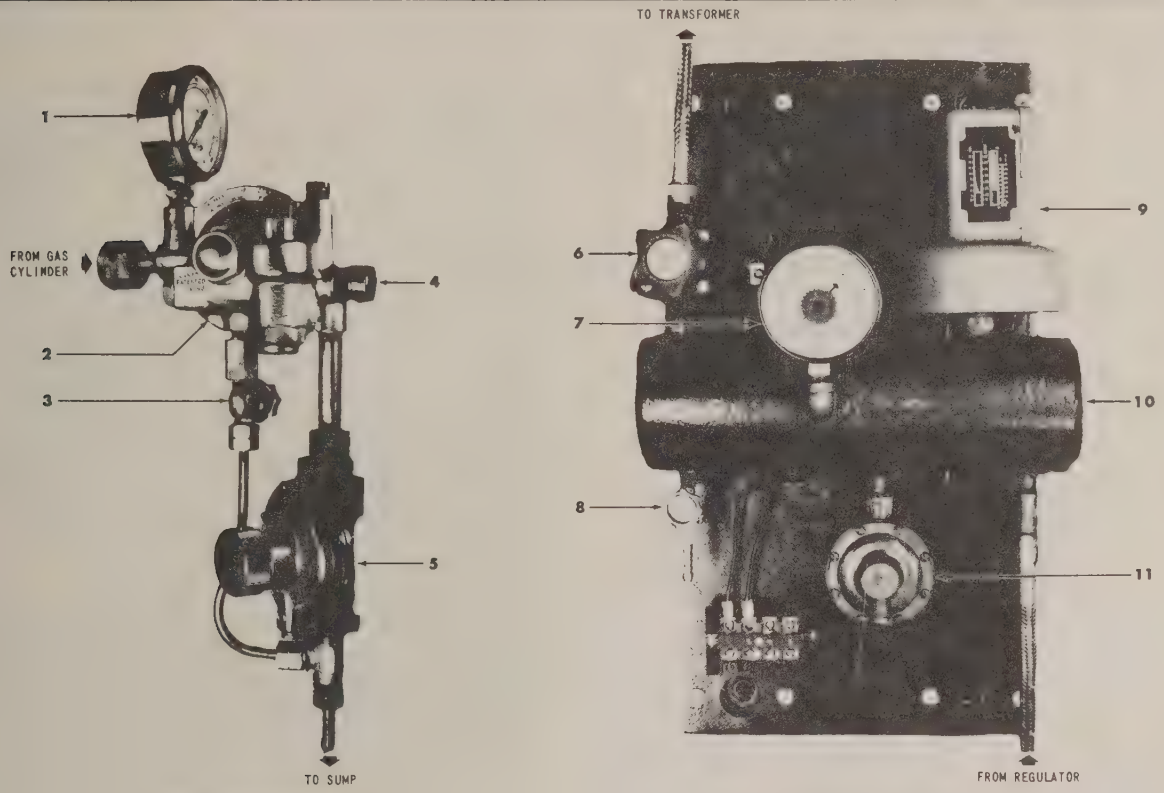
Install the control cabinet (if shipped separately) as shown on the transformer outline drawing. Install any gas piping that has been removed. Where compression-type gas fittings are used, be sure that the small metal sleeve that is force-fitted to the piping is in place before a pipe connection is made. Bolt the gas cylinder in place in the cabinet.

The coupling between the gas regulator and cylinder is of the ball-joint construction. Unless the seats are in perfect condition there will be a gas leakage. It is recommended that each time an assembly is made, the ball joint on both the regulator and cylinder be cleaned with very fine steel wool. Remove all metal particles or foreign material before assembling. *Do not use* emery cloth or sand paper.

Before connecting the regulator, open the gas cylinder valve slightly to remove any dust which may have accumulated and make sure the threads are clean and in good condition. Open valves (6) and (8), Fig. 2, to allow any oil present to drain from the piping and sump. Attach the regulator to the gas cylinder and connect the flexible tubing to the third stage of the regulator.

APPLYING THE GAS SEAL

With valves (6) and (8) closed, open the gas cylinder valve *very slowly* to avoid a sudden shock on the regulator. With the regulator operating properly, pressure gage (7) should indicate approximately ½ psi. If this is the



A. GAS REGULATOR

B. SUPERVISORY ASSEMBLY

1. *Gas cylinder pressure gage*
2. *First two stages of regulator*
3. *Third stage bypass valve*
4. *Relief valve*
5. *Third stage of gas regulator*
6. *Transformer feeder valve*
7. *Transformer pressure gage*
8. *Sump drain valve*
9. *Transformer low-pressure alarm switch*
10. *Sump*
11. *Automatic bleeder*

Fig. 2. Gas control equipment

case, valve (6) may be opened to pressurize the transformer. Make sure the gas cylinder valve is fully opened to complete its seal and that all valve stem packing glands are tight. Also make sure the oil in the transformer is at the proper level, since any excess will cause an unnecessary loss of gas at normal operating temperatures.

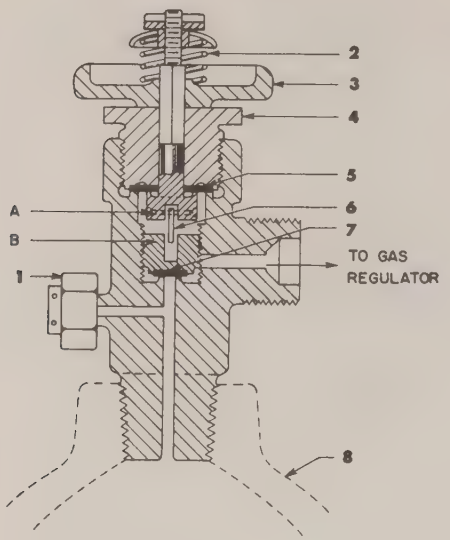
If it is desired to make a leak test or to check operation of the regulator before placing the transformer in service, proceed as outlined under "Gas Leaks" or "Regulator Test."

During the first few weeks of operation, the small amount of oxygen in the space above the oil will combine chemically with the oil, leaving only nitrogen. However, if it is the User's practice to purge the gas space with dry nitrogen, this can be done by opening the gas sampling valve on the transformer control center and opening third stage bypass valve (3). Allow nitrogen (from the second stage at 11 psi) to flow until the escaping gas tests five percent oxygen or less. After 24 hours, analyze the gas again and repeat the flushing operation if necessary. No more than three flushings should be required.

MAINTENANCE

Over a period of time oil vapor from the transformer will condense in the gas piping and collect in the sump (10). Drain valve (8) should be opened occasionally to remove this oil and prevent it from entering the regulator. To change gas cylinders, close feeder valve (6) and the gas cylinder valve. Disconnect the regulator and install the new cylinder, making sure that the fittings are clean and in good condition. Re-establish the gas seal as explained under "Installation."

NOTE—If for any reason a vacuum is to be drawn on the transformer, the gas control equipment must be protected by closing feeder valve (6).



1. Relief disc
2. Compression spring
3. Hand wheel
4. Gland
5. Packing (back seat)
6. Driver pin
7. Main valve seat
8. Gas cylinder

Fig. 3. Gas cylinder valve shown in closed position

NITROGEN CYLINDERS

It is recommended that a spare gas cylinder be kept on hand at all times. Orders for this gas should specify "Special dry nitrogen to General Electric specification D27A3A2". It can be purchased from the Air Reduction Sales Company in cylinders containing 220 cu. ft. of gas at atmospheric pressure, compressed to 2000 psi at 70F. Filled cylinders are carried in stock and empty ones can be refilled at the following locations. Empty cylinders should be returned with a slight positive pressure to avoid contamination.

Acton, Albion (bulk only), Alton, Arlington, Atlanta, Baltimore, Baton Rouge, Beaumont, Bethlehem, Bettendorf, Birmingham, Boston, Buffalo, Calvert City, Central Falls, Charlotte, Chicago, Cincinnati, Cleveland, Corpus Christi, Dayton, Detroit, El Paso, Flint, Grand Rapids (OP only), Houston, Jersey City, Johnstown, Louisville, Midland, Milwaukee, Minneapolis, Mobile, New Orleans, Oklahoma City, Pittsburgh, Richmond, Riverton, St. Louis, Shreveport, Waycross, Wheeling, Wichita.

EXCESSIVE LOSS OF GAS

Excessive consumption of gas can be the result of a high oil level, abnormal loading, a defective regulator or leaks. If the oil is at its proper level and load changes have been nominal, the cause can be determined by keeping a log of oil temperature, transformer pressure and gas cylinder pressure. If the losses continue while the transformer pressure remains above ½ psi, gas is most likely entering the tank at too high a pressure, resulting in excessive operation of the bleeder. Tighten the third stage bypass valve (3) and if this does not correct the difficulty, check the regulator as explained under "Defective Regulator". If a large pressure reduction occurs in the transformer without a corresponding change in temperature, make an inspection for leaks.

Gas Leaks

While the factory subjects all transformers to a thorough test for leaks, and every effort is made to produce airtight tanks and accessories, leaks do occasionally develop. (The loss from a gas leak at the rate of 1/16-inch bubble per second amounts to only 2¼ cu ft. per year, which is practically negligible considering that the gas cylinder holds 220 cu ft. at atmospheric pressure).

To test for leaks, separate the transformer and its gas piping from the sump, gages, regulator and gas cylinder by closing feeder valve (6). Open third stage bypass valve (3) and allow the pressure on gage (7) to increase until it is slightly less than the operating pressure for bleeder (11). Close the gas cylinder valve and observe pressure gage (7). The pressure should remain constant, although a drop not exceeding ½ psi per hour is permissible since this results in a loss of only a few cubic feet per year.

A decline in pressure on the gas cylinder gage (1) does not necessarily indicate a leak, as the small volume of high-pressure gas locked between the valve and regulator may escape along the stem of the gas cylinder valve. During normal operation, the valve should be tight against the back seat and no gas should escape around the stem unless the back seat has developed a leak.

If the pressure drop on gage (7) is more than ½ psi per hour, apply a solution of one part water and one part liquid soap to the valve stems, couplings, gasketed joints and flexible hose. Apply the solution with a squirt can rather than a brush so that no bubbles will form and make a thorough examination for bubbles created by leaking gas.

If repairs are made or no leaks are found, but the pressure continues to fall off, the transformer low-pres-

sure alarm switch, the transformer high-pressure alarm switch (if furnished), or perhaps the pressure gage itself may be at fault. They can be checked by removing one at a time and plugging the holes—or in the case of the gage, by replacing with another.

To check the high-pressure system, close bypass valve (3), *slowly* open the gas cylinder valve, and make a soap solution test of all high pressure components from the gas cylinder to the third stage of the regulator. If the coupling between the gas cylinder and regulator leaks, remove the regulator and thoroughly clean both surfaces of the ball joint with fine steel wool. Slightly open the cylinder valve to blow out any dust and reassemble the coupling, making sure connections are tight.

To check the second half of the system consisting of the transformer and the gas piping to it, close valve (3) and *slowly* open the gas cylinder valve. Open valve (6) and then open valve (3) until the pressure on the transformer builds up to a value slightly less than the operating pressure for bleeder (11). Close valve (3) and the cylinder valve and observe pressure gage (7) over a period of 6 to 24 hours. If there is an appreciable drop, continue the soap solution test of all joints and components associated with the transformer gas space.

If a thorough examination by the liquid soap method fails to locate the leak or leaks, a more sensitive test can be made by the use of a halogen leak detector, as explained in instructions furnished with that equipment. Complete the test as rapidly as possible and then thoroughly flush the gas space with nitrogen or exhaust with a vacuum line to purge out the halogen gas.

If any components are found to be defective, replacements can be ordered from the nearest Apparatus Sales Office of the General Electric Company. *A leaking cylinder-pressure gage (1) requires a complete new regulator.*

Regulator Test

To check the operation of the complete three-stage regulator, close valves (3) and (6) and *slowly* open the gas cylinder valve until it is tight against the back seat. Note the pressure, as indicated on pressure gage (7), at equal time intervals. If the regulator is functioning properly the pressure should not rise. Due to the small gas volume involved, a slight increase such a ½ psi per hour is permissible. If the pressure rises appreciably, it is an indication that the third stage of the regulator is defective or that the third-stage bypass valve (3) is open slightly.

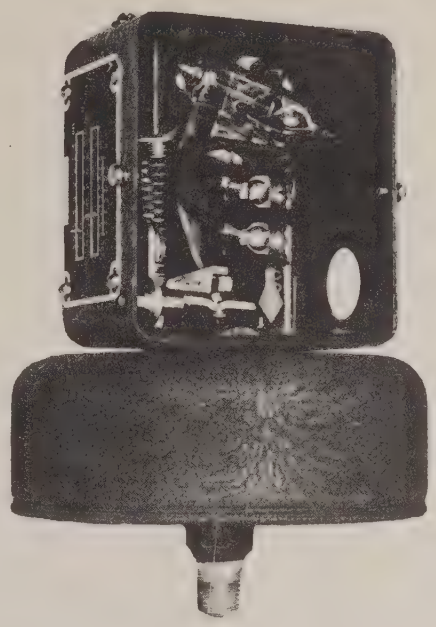


Fig. 4. Transformer low-pressure alarm switch

If the regulator is found to be faulty, do not attempt to repair it and do not return it to the regulator manufacturer. Contact the nearest Apparatus Sales Office of the General Electric Company for a replacement and return of the defective regulator.

Persistent Gas Loss

If difficulty is experienced in locating the trouble, take readings of ambient and top-oil temperatures, tank and cylinder pressures and load conditions at least every four hours over a period of several days. Send this data, along with the rating and serial number of the transformer, to the nearest Apparatus Sales Office for the General Electric Company. A study of the data will then be made to determine what steps should be taken.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

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Insulating Oil
And
Transformer Drying

10C® INSULATING OIL

The use of oil as an insulating medium in transformers requires that it have a high dielectric strength. The presence of impurities, particularly moisture, in the oil may lower its dielectric strength to such an extent as to make it unsafe for use. These instructions cover the care and maintenance of 10C oil to obtain the best service from it.

The transformer is normally shipped oil filled, ready for service. When conditions require removal of the oil during transit, the transformer will be shipped gas-filled and the oil will be shipped separately in 55 gallon drums. Large quantities may occasionally be shipped in tank cars or trucks. Fill the unit in accordance with the instructions supplied with gas-filled transformers.

General Electric 10CA* oil consists of G-E 10C oil with an inhibitor, DBPC (2, 6 di-tertiary butyl para cresol) added to improve its oxidation characteristics. The two oils are interchangeable and can be mixed in any proportion, with a corresponding dilution of the inhibitor.

HANDLING AND STORING

When oil is received in separate containers, the equipment used in transferring it must be absolutely clean and dry. If the transformer is located outdoors, adequate precautions must be taken to insure that no dirt or moisture enters the oil during the filling operation. Before opening a container allow it to stand until the oil is at least as warm as the surrounding air.

Use only metal or oilproof synthetic rubber hose for oil lines. The sulphur in natural rubber hose will dissolve in the oil and prove harmful to the copper in the windings.

Before placing the oil in the transformer take a sample from each container and make dielectric test as outlined under "Sampling" and "Testing". If the oil tests are unsatisfactory restore the dielectric strength before placing the oil in the transformer. When transferring the oil from containers to the transformer it is recommended that the oil be passed through a filter press to remove any undetected moisture or sediment which may be present.

10CA oil can be handled in the same manner as 10C oil and with the same equipment. Instructions on handling the inhibitor itself and the procedure for adding it to 10C oil are contained in a technical publication, GET-2486. Should it become desirable to add DBPC to reconditioned or new oil in the field, copies of this publication can be obtained from the nearest Apparatus Sales Office of the General Electric Company.

WARNING—Static charges can be developed when oil flows in pipes, hoses, and tanks. To accelerate dissipation of the charge in the oil, ground the filter press, transformer tank, and all windings (if accessible) during the oil pumping and filtering operation. Since conduction through the oil is slow, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped.

Store drums or cans containing oil in a closed room. Keep the bungs tight. If necessary to store oil outdoors, protect the containers from the weather and direct contact with water. Regardless of location, all drums should be stored in a position which results in the bungs being under a positive pressure. Do not open a drum or can until the oil is actually needed. Any change in temperature while the containers are open will cause an exchange of air between the container and the room with the possibility of moisture entering the oil. Partially emptied drums must be tightly resealed and stored in the same manner as above.

SAMPLING

The accuracy of test data can be seriously affected by improper sampling. In order to obtain consistent results it is recommended that the methods outlined in the latest revision of ASTM Designation: D923 be observed.

Strict attention should be given to the cleaning and drying of sampling and testing receptacles. Samples should be taken when the insulating liquid is at least as warm as the surrounding air to avoid the possibility of moisture condensation. If the transformer or drum is outdoors, the sample should be taken on a clear day with precautions being taken to guard against contamination by windblown dust, etc. The more important features of the sampling procedure are outlined in the following steps:

SAMPLING FROM TRANSFORMERS

1. Impurities which tend to affect the dielectric strength of 10C oil will generally be found at the bottom of the transformer and therefore the sampling valve is located on the main drain valve.

2. Three types of containers are recommended for sampling purposes — a one-quart, small-neck, brown glass bottle; a clear glass bottle in a lightproof carton; or a one-quart tin can that has had the solder seams thoroughly cleaned to remove all traces of soldering flux. Do not use rubber stoppers or rings. If desired, glass sampling bottles may be obtained from the General Electric Company as explained under "Testing Service".

3. To clean the bottles, rinse with non-leaded, oil-free gasoline. Then wash with strong soapsuds, rinse thoroughly with distilled water, and dry in an oven at 105C to 110C for at least 8 hours. After drying, the bottles must be tightly sealed with glass stoppers or with clean corks protected by clean metal foil. Store them in a dry, dust-free cabinet or compartment.

4. Carefully clean the sampling valve or plug and allow enough insulating liquid to run out to remove any moisture or foreign matter which may have collected.

5. Rinse the bottle carefully, at least three times, with small portions of liquid drawn from the sampling valve. Allow the sampling bottle to drain thoroughly between rinses.

* TRADEMARK OF THE GENERAL ELECTRIC COMPANY

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GENERAL ELECTRIC

Fig. 1. Typical high-voltage A-C test set

6. Draw a sample into the bottle, leaving sufficient air space to allow for possible expansion of the liquid. Reseal the transformer and carefully seal the container to prevent exposure to the atmosphere.

7. When making repeated samplings, observe the transformer liquid level and add make-up as required.

SAMPLING FROM DRUMS

1. Drums should remain undisturbed for at least eight hours before being sampled.

2. Glass thieves should be cleaned, dried, and stored in the same manner as outlined for bottles.

3. Take the sample about ⅛" from the bottom, observing the precautions previously outlined.

SAMPLING FROM TANK CARS

Although the method called for in the standards requires a tank car thief, from a practical standpoint satisfactory samples can be obtained from the bottom valve of the tank car. The valve exterior should be thoroughly wiped off and a few quarts of oil should be discharged to clean the valve interior before taking the sample.

TESTING

DIELECTRIC STRENGTH

Follow the technique specified by the American Society for Testing and Materials, Designation: D877. A variety of high-voltage dielectric testing equipment may be purchased from the General Electric Company for this purpose. (See Figs. 1 and 2). The following paragraphs give a general outline of the procedure:

1. Set the spacing of the 1.0 inch diameter electrodes at 0.100 inch.

2. Wipe the test cup and electrodes clean with dry, calendered tissue or clean, dry chamois and thoroughly rinse with non-leaded, oil-free, dry gasoline.

3. Fill the test cup with dry gasoline and make a breakdown test under standard conditions of voltage application (3 kv per second rise). If the cup has a dielectric strength above 25 kv, it is considered suitable for testing purposes. Observe the usual precautions in handling gasoline.

4. Immediately after the final rinsing with gasoline, rinse the test cup with the sample under investigation, and proceed with the test at once.

5. *The temperature of the sample when tested should be the same as that of the room, which should be between 20 C and 30 C (68 F and 86 F).* Tests made on samples above this temperature can be misleading. Under no circumstances should the test cup be colder than the sample being tested.

6. Agitate the sample gently before each filling to prevent variations in results due to a settling of contaminants. Pour the liquid into the receptacle slowly to avoid the formation of air bubbles and fill to overflowing. If air bubbles are present, gently rock the test cup a few times and wait at least 3 minutes before applying voltage.

7. Fill the cup at least five times, making one test per filling, and average the results.

Since the oil is a major portion of the insulation system in the transformer, its dielectric strength should be maintained as high as possible. A low breakdown voltage is an indication that impurities such as moisture, conducting dust, lint, or carbonized particles have entered the oil. Oil testing lower than 26 kv (30 kv when new) should either be filtered to bring it back to its original condition or be replaced, depending on the condition of the oil and economic considerations. Under normal operating conditions values of 30 kv and above can frequently be maintained.

OTHER TESTS

Although a low dielectric strength indicates the presence of contaminants, a high value is not always a certain indication of their absence. A number of other tests can be performed on an insulating oil to determine its condition and therefore no one test should be considered conclusive. ASTM Designation: D117 defines the standard tests and contains cross references to other ASTM Designations for detailed descriptions of each method. Several of the more significant tests are listed in the following paragraphs.

Where suitable equipment and qualified personnel are not available for conducting these tests, samples can be returned to the factory for laboratory analysis as outlined under "Testing Service". Use sample bottles supplied by the General Electric Company for this purpose.

VDE Test Cell

Where a more sensitive test of dielectrict strength is desired, the VDE test cell (ASTM Designation: D1816) can be used. (See Fig. 2.) The spherically-

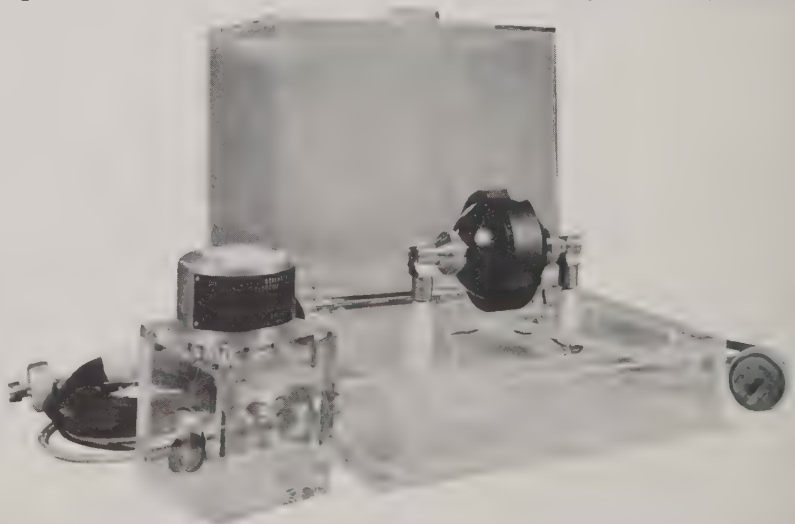


Fig. 2. VDE test cell (left) and ASTM cell mounted on cage (right)

capped electrodes used in this method are more sensitive to contaminants that lower the dielectric strength of an oil, and also give a higher evaluation to the dielectric strength of uncontaminated oils than the type of electrodes used in Method D877.

Acidity (Neutralization)

The acidity test is one of the most satisfactory indicators of oxidation in the oil. This is true because some of the oxidation products are of an acid nature and thus may be detected by measuring the acidity of the oil. The main hazard of oxidation is the deposition of sludge. Sludge occurs after the oxidation products held in solution finally saturate the oil and any additional products formed settle out in solid form. The acidity test indicates fairly accurately how far oxidation has progressed.

ASTM Designation: D1534 covers a simple procedure that can be applied in the field. Where a quantitative neutralization value is required, Designation: D664 or D974 is recommended for laboratory use.

Water Content

The presence of free water may be disclosed by visual examination in the form of separate droplets or as a cloud dispersed throughout the oil. However, water in solution cannot be detected visually and therefore the Karl Fishcher Reagent method (ASTM Designation: D1533) is recommended as a means of determining total water in the oil in parts per million.

TESTING SERVICE

For convenience in sampling and testing, the General Electric Company will, upon receipt of an order covering the actual cost of testing, furnish one-quart sample containers. These will be supplied filled with clean, dry oil to prevent contamination of the bottle. Unless the transformer is already open and it is convenient to add this oil as a replacement, it should be discarded. After emptying the container, immediately refill with the oil to be tested. Since reliable tests are dependent on reliable samples, follow the technique outlined under "Sampling".

Send samples to the Laboratory, Medium Transformer Department, General Electric Company, Rome, Georgia. Pack these samples carefully to avoid breakage in transit. Recommendations for continued use or treatment will be furnished, based on the following tests.

1. Dielectric strength
2. Acidity
3. Water content
4. Color
5. Condition

To assist the laboratory in furnishing the most useful recommendations from the results of the tests, supply the following information:

1. Give the serial number and rating of the transformer.

2. State why the tests are considered desirable.

3. State whether or not the sample represents the liquid originally furnished with the transformer and if not, when and why it was replaced.

4. State the date, transformer top-oil temperature and weather conditions when the sample was taken.

5. Give any other information that might have a bearing on the condition of the liquid.

6. State to whom the report should be sent.

Additional testing services are available should the need arise. For further information concerning specific problems, consult the nearest Apparatus Sales Office of the General Electric Company.

MAINTENANCE

The oil must be maintained at the proper level in the transformer and its dielectric strength should be tested after the first few days of operation, again after six months, and yearly thereafter. Keep accurate records of the tests and filter or replace the oil as required.

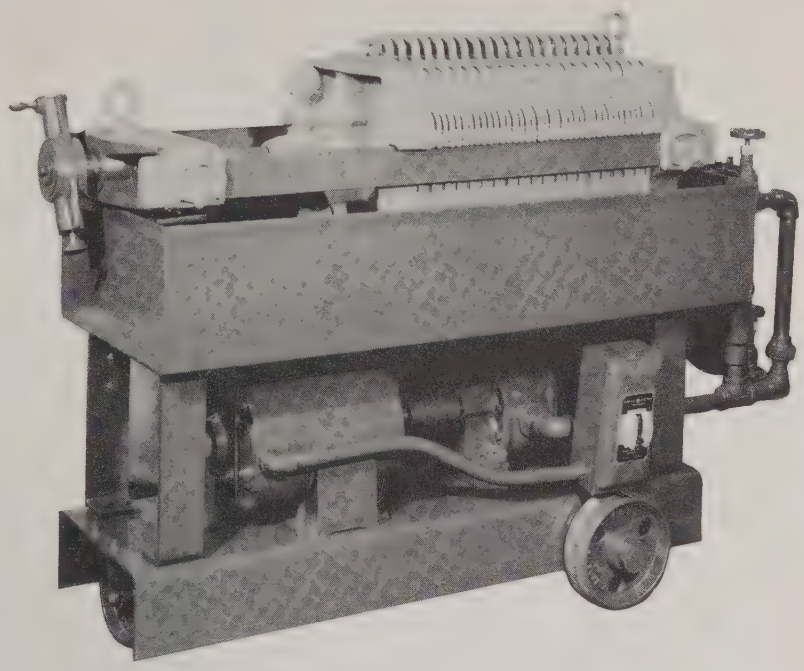


Fig. 3. Typical filter press equipment

FILTERING

If tests on the oil indicate that moisture or other contaminants are present, they can usually be removed by passing the oil through a filter press (Fig. 3). Filtration can be accomplished in the transformer or other container by circulating the oil from the bottom to the top through a filter press. However, this method is quite slow since the filtered oil is continuously being mixed with the unfiltered. Filtering can be done faster and more efficiently by passing the oil into a separate, clean, dry container. In this manner, all of the oil is given one complete pass through the filter press. If additional filtering is required, the oil can then be filtered back into the transsformer or returned to the shipping drums after making sure they are clean and dry.

The filter press will not remove large quantities of free water from the oil. When a large quantity of free water is introduced into the filter it will be passed on through, emerging as finely divided droplets dispersed throughout the oil. Therefore, if free water is present in the bottom of the transformer, it should be drained off before filtering is started. When filtering from drums, either drain off the free water or filter only that part of the oil which is several inches above the water and then accumulate the remainder in a

smaller container where the water can be more readily separated.

To effectively dry the oil, the paper in the filter press must be dry. Frequent samples of the outgoing oil should be tested and when the dielectric strength drops below 26 kv, change the papers. For details of the filtering procedure refer to instructions GEH-754, copies of which are available upon request. For information on oil drying and filtering equipment or recommendations on oil storage and filtering systems, contact the nearest Apparatus Sales Office of the General Electric Company.

A transformer contaminated with moisture will not only have moisture suspended in the oil, but also in the windings and insulation. The most efficient temperature for filtering moisture from the oil is between 20 C and 40 C, but at this temperature the transfer of moisture from the windings and insulation to the insulating liquid is quite slow. In order to completely dry the transformer, the filter-press operation should be followed by one of the drying methods outlined under "Drying a Transformer".

DRYING A TRANSFORMER

Drying of oil-immersed transformers is necessary when evidence of moisture is found. Visual inspection may reveal signs of condensation or free water and dielectric tests of the insulating liquid will give an indication of the moisture content of the oil. However, a more meaningful indication of the condition of the entire insulation system can be obtained by making power factor measurements on the transformer. In general, oil-filled transformers should have a power factor of 2 percent or less (corrected to 20 C — see Fig. 4.). Those having load-tap-changing equipment may be slightly higher but figures much in excess of this value indicate the presence of moisture or other contaminants and should be questioned. A small, portable power factor test set similar to the General Radio Capacitance Bridge, Type 1611-A, may be used for this test as explained under "Power Factor Measurements".

Recommendations regarding the drying of any particular transformer can be obtained from the nearest Apparatus Sales Office of the General Electric Company. Requests for this information should include the serial number of the transformer and the voltages and kva available for drying, including any available step-up or step-down transformers.

The first step in drying a transformer consists of removing any free water and the water in solution with the oil as previously explained under "Filtering". The second step involves removal of the moisture from the windings and insulation and any of the following drying methods will produce satisfactory results if carefully performed. *Exercise caution when heating the transformer to avoid damaging the insulation.* The maximum winding temperature as determined by resistance measurements should not be allowed to exceed 95 C. CAUTION—Any drying method which involves heating the transformer when it is exposed to the atmosphere also creates a serious fire hazard. No smoking or open flames should be permitted near the transformer and suitable fire extinguishers, preferably the carbon dioxide type, should be on hand before beginning the dryout.

SHORT-CIRCUIT METHOD

This method consists of heating the windings and oil to a specified temperature with one winding short-circuited and a suitable voltage applied to the other winding. The moisture, which is driven off in the form of vapor, is vented to the atmosphere by removing the manhole covers and pressure relief device. Air circulation above the oil can be improved by the use of fans. Protect all openings in the cover of the transformer from inclement weather.

Proper oil temperatures can be obtained more readily by blanketing the transformer or by reducing the oil circulation. Regardless of the amount of blanketing around the main tank, the cover and sides of the transformer down to the oil level must be insulated to prevent condensation on the inside.

If the unit is to be blanketed, the amount required will have to be determined by trial. Begin at the bottom and wrap the transformer with heavy paper, cloth, or building felt until sufficient radiating surface has been covered.

An effective means of limiting heat losses through the cooling tubes is to lower the oil level to restrict or prevent circulation. On transformers equipped with removable radiators, the flow of oil can be regulated by adjusting the radiator valves. Caution—Do not leave both top and bottom radiator valves closed at the same time as damaging hydrostatic pressures can develop. The flow of oil on forced-oil units can also be controlled to regulate heating.

When drying a forced-oil, air-cooled transformer, the required top-oil temperature can be obtained by reducing the number of unit coolers in operation. However, at least one unit cooler must be in operation at all times. For forced-oil, water-cooled transformers, one oil-circulating pump must be in operation at all times. The temperatures shown in Table I can be obtained by regulating the flow of air or water through the cooler. Ordinarily it will not be neces-

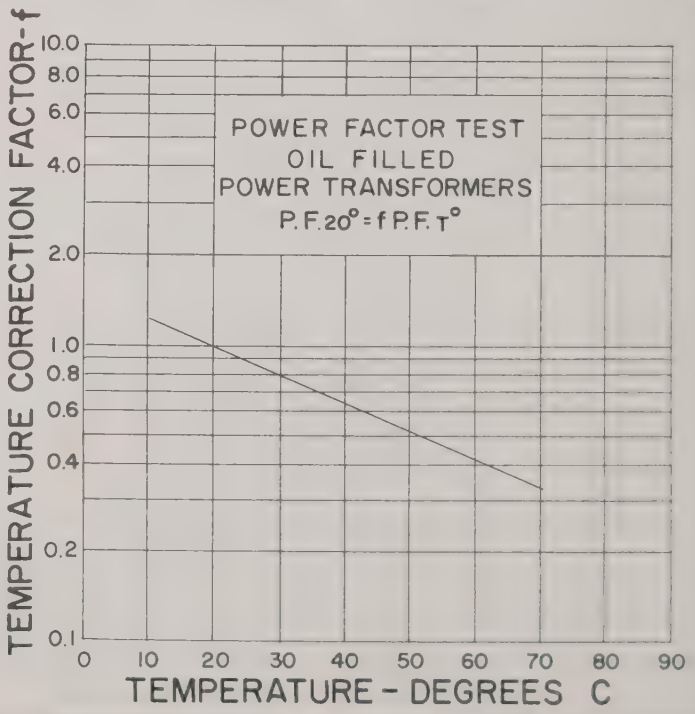


Fig. 4. Temperature correction curve for power factor measurements on oil-filled transformers

sary to exceed 85 percent load current in order to obtain the required top-oil temperature.

On conservator-type transformers it will be necessary to lower the oil level at least 6 inches below the cover to allow for expansion as the oil heats up and to permit free circulation of air. It is also recommended that the pressure relief pipe be removed to provide additional ventilation and avoid the condensation problem.

POWER REQUIREMENTS FOR TWO-WINDING TRANSFORMERS

When drying a transformer by the short-circuit method, one winding of the transformer is short-circuited and voltage is applied to the other winding. Only a fraction of the rated voltage of the winding can be applied and to insure proper drying, all portions of all the windings must be in the circuit. Be sure the conductor used to short-circuit the windings will carry the required current.

While the equations which follow show the method of computing the required voltage and kva at FULL LOAD CURRENT it should be noted from Table I that it is preferable to hold less than full load current in order to permit higher top-oil temperatures for more effective and faster drying. However, having once established from the equations the voltage and kva required at full voltage load current, corresponding values of current and kva at available voltages can be readily calculated by noting that the current will vary directly as the ratio of

$$\frac{E \text{ (Available)}}{E}$$

and kva will vary as the square of this ratio.

The equations for computing the required voltage and kva for drying a SINGLE-PHASE, TWO-WINDING transformer at full load current are as follows:

$$E = \%IZ \times E_R$$

$$KVA = \frac{E \times I}{1000}$$

The equations for computing the required voltage and kva for drying a THREE-PHASE, TWO-WINDING transformer at full load current are as follows:

$$E = \%IZ \times E_R$$

$$KVA = \frac{1.732 \times E \times I}{1000}$$

%IZ = percent transformer impedance volts from nameplate.

E_R = nameplate voltage of winding to which power is applied. When tap changers, terminal boards, or load-tap-changing equipment are located in either or both windings, they must be set on the position which places all sections of the windings in the circuit, leaving no turns idle.

I = full load current corresponding to maximum rated voltage.

E = required drying voltage for full load current.

KVA = required kilovolt-amperes for full load current

If it is necessary to obtain drying voltage over a long transmission line, overvoltage protection should be provided.

OTHER TRANSFORMERS

The drying of three-winding transformers and autotransformers with tertiary windings by the short-circuit method usually is more complicated than that of two-winding transformers because of the differences in impedance and capacity of the windings. It is frequently necessary to make two separate drying runs on such units to assure that all windings will be properly dried. In some cases, division of the load current in the various portions of the windings can be obtained by the insertion of an additional reactance, permitting all three windings to be dried simultaneously. It is recommended that detailed information for drying three-winding transformers be obtained from the nearest Apparatus Sales Office of the General Electric Company.

LOADS AND TEMPERATURES

If power is available, up to 125 percent load current can be held at the start of the drying run until the top-oil temperature reaches 65 C. The load on the transformer must then be reduced to obtain a constant top-oil temperature in accordance with the following table:

TABLE I

Max. Allowable Short-Circuit Amps in Percent of Full Load Based on Min. Rating	Maximum Allowable Top-Oil Temperature in Deg. C
50	85
85	80
100	75

It is recommended that an 85 C top-oil temperature be held with 50 percent load, if possible, since the fastest drying will take place at the highest temperature. Should an 85 C top-oil temperature with 50 percent load be unobtainable, the nearest percent load and corresponding value of top-oil temperature should be used.

Do not allow the top-oil temperature to exceed the value specified for a given percent load, since the windings are at a higher temperature than the oil and damage to the insulation may result. It is recommended that the top-oil temperature never be allowed to exceed 85 C. Make sure that the thermometers used are accurate and that the top-oil temperatures are accurately observed. Only spirit thermometers should be used inside the transformer.

WHEN TO DISCONTINUE DRYING

During the drying run, take oil samples every four hours from both the top and bottom of the transformer and test them for dielectric strength. Take the top sample from a manhole opening and the bottom sample from the sampling valve provided on the drain valve. Allow the samples to cool to room temperature (not more than 40 C) before testing. Plot curves of the oil tests, top-oil temperatures, and the load current against time. These curves will picture the progress of the drying.

While moisture is being given off, the top-oil samples may test lower than the bottom samples. A decrease in the dielectric strength of the oil indicates that moisture is still passing from the transformer windings into the oil. When the windings and insulation are dry, the oil begins to increase in dielectric strength and it is not uncommon to have it reach 30 kv or more.

Continue the drying until the oil from both top and bottom tests 26 kv (preferably 30 kv or higher) for seven consecutive tests taken four hours apart with the oil maintained at a maximum temperature for the load held and without filtering. If desired, power factor measurements on the transformer may be used to supplement dielectric tests on the oil as a means of determining drying progress. Refer to "Power Factor Measurements".

After termination of the drying run, add clean, dry oil of high dielectric strength (26 kv or above) to fill the tank to the proper level. It is recommended that the filling of the transformer be completed from the top of the tank or conservator rather than through the drain valve, as, in the latter case, air bubbles accidentally entering with the oil may be trapped in the windings and insulation.

If the transformer is rated 160 kv or higher, it should, if possible, be operated for 24 hours at approximately two-thirds voltage (no load) while at high oil temperature, making similar tests of oil samples. (Obtain top-oil samples from one of the air vents on conservator-type tanks.) After satisfac-

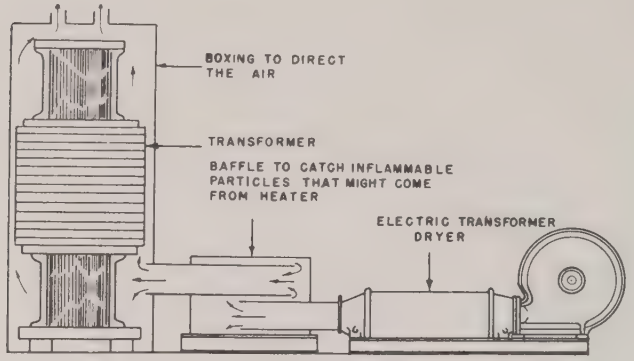

BOXING TO DIRECT THE AIR
TRANSFORMER
BAFFLE TO CATCH INFLAMMABLE PARTICLES THAT MIGHT COME FROM HEATER
ELECTRIC TRANSFORMER DRYER

Fig. 5. Hot air method of drying.

torily making the two-thirds voltage test, apply full voltage (no load) for 24 hours and make the same tests. Water-cooled or forced-oil-cooled transformers may require a small flow of the cooling medium to hold the top-oil temperature within the 85 C limit on this test.

HOT-AIR METHOD

This method consists of placing the core and coil assembly in an enclosure and forcing clean air at a temperature of 100 C through the oil ducts in the windings. Blanketing of the enclosure will help maintain the required temperatures and holes should be provided at the top and side or bottom as shown in Fig. 5. The clearance between the coils and sides of the enclosure should be small with pipes or deflectors used as required to direct the hot air through all parts of the windings. An electric transformer dryer of the type shown can be purchased through the nearest Apparatus Sales Office of the General Electric Company.

CAUTION—Do not let oil run from the transformer into the heater, for it may cause a serious fire. To minimize the fire risk, place a baffle in the pipe line between the heater and the transformer, so that, should any trouble occur in the heater, sparks will not reach the transformer. This baffle can be made from a section of sheet-iron pipe covered with asbestos, and should be approximately 16 inches in diameter and 48 inches long.

To obtain the best results, keep the temperature of the incoming and outgoing air about the same. The quantity of air required to do this varies with the size of the transformer, the following being an approximate guide.

Area of Tank Base - Sq. Ft.	Air CFM
30	1000
60	2000
100	3000
125	4000
150	5000

Drying in this manner may also be accomplished with the core and coil assembly in its own tank, providing sufficient air flow can be directed up through the windings.

A fairly accurate indication of the drying progress can be obtained by observing the trend of power factor or megger readings over a period of time. Continue drying until the readings become approximately constant at a constant temperature. See "Power Factor Measurements".

POWER FACTOR MEASUREMENTS

When taken for the purpose of determining initial dryness, the power factor reading should be corrected to 20 C using the curve shown in Fig. 4. For practical purposes, the temperature of the insulation may be considered to be the same as the top oil temperature.

When used to determine drying progress, take readings at 4 hour intervals and plot a curve of these values as a function of time. No temperature correction factor need be used in this case, since the general trend of the readings over a period of time will give a fairly accurate indication of the moisture removal. When the curve has leveled out for a period of 24 hours, the transformer has reached the maximum degree of dryness obtainable with the method of drying being used.

USING A CAPACITANCE BRIDGE

If the General Radio Capacitance Bridge, Type 1611-A, or equivalent is to be used in determining power factor, the three measurement method is recommended (for two-winding transformers). Refer to the manual supplied with the bridge for instructions on how to zero adjust the instrument, compensate for capacitance in the leads, and the formulas for determining the true readings when there is an effect from extraneous voltages.

Precautions should be taken against the possibility of an "induction kick" when measurements are being made. The shield of the high voltage test lead (positive terminal on the bridge) is to be connected to the guard circuit. NOTE—This is the only use that can be made of the guard for transformer testing. Use care in selecting the proper multiplying scale as poor readings will result when using an improper scale. The bridge will give readings of capacitance and dissipation factor directly and for the purpose of these measurements, dissipation factor and power factor may be considered to be the same for values up to about 20%.

1. Isolate the transformer from all external leads.

2. Ground the tank.

3. Short circuit each winding at its bushing terminals.

4. Connect the "positive" test lead to a winding (or windings) and the "negative" lead to ground (or ground and one winding) and record the capacitance and power factor for the following three conditions.

	"Positive" Lead to:	"Negative" Lead to:
A.	High	Low and Ground
B.	Low	High and Ground
C.	High and Low	Ground

5. The power factor between the high- and low-voltage windings is the most significant for determining the dryness of the transformer. This value can be calculated from the preceding measurements as follows:

$$PF_{H\text{-}L} = \frac{(PF_A \times C_A) + (PF_B \times C_B) - (PF_C \times C_C)}{C_A + C_B - C_C}$$

Accessories

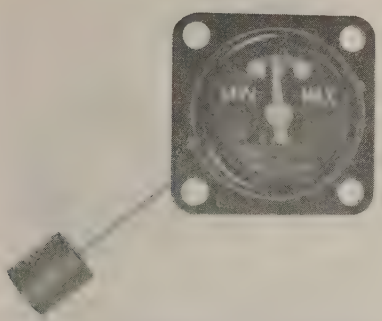


Fig. 1. Magnetic liquid-level gage with three-inch dial

LIQUID-LEVEL GAGE

Magnetic liquid level gages, Figs. 1 and 2, are used to indicate the level of the insulating liquid in the main transformer tank and in associated compartments. The gage consists of a float arm and magnet on one side of a liquid-tight partition and a second magnet and indicating pointer on the other side. See Fig. 3. The gage can be removed whenever the liquid is at or below the 25C level.

Gages which have a snap-action switch can be wired to give an alarm when the liquid level approaches a point too low for safe operation of the transformer. A cam on the indicator shaft will operate the switch when the pointer drops to the "LOW" mark on the dial. As the liquid level rises the pointer indicates the change, but the switch will not clear the alarm circuit until the pointer has advanced from five to ten degrees above the "LOW" mark. Switch contacts are connected to a three-conductor cable as shown in Fig. 8 and have an a-c rating of 15 amperes at 125, 250 and 480 volts, and a d-c rating of .50 amperes at 125 volts and .25 amperes at 250 volts.

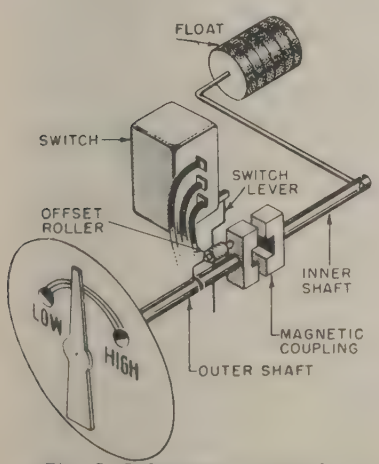


Fig. 3. Schematic view of magnetic liquid-level gage with alarm switch

LIQUID TEMPERATURE INDICATOR

The liquid temperature indicator is used to indicate the top liquid temperature of the transformer. Its dial is calibrated in degrees centigrade with a white or yellow pointer to indicate top liquid temperature and a red pointer to show the maximum temperature reached since last reset. The type AL device has no switches and is mounted locally at the transformer's top liquid level.

The type ALR liquid temperature indicator relay is similar to the type AL except that it has internal switches for controlling fans, pumps, and/or for initiating an alarm. The liquid temperature indicator relay can be furnished with two or three switches at local (top liquid level) or at eye-level mounting.

Dial readings taken at frequent intervals will aid in detecting abnormal conditions affecting the transformer, but should not be relied upon as an indication of permissible load.

LOCAL MOUNTING

The thermometer is mounted with its temperature-sensitive bulb inserted in a well which extends into the insulating liquid at the top of the transformer. The well is liquid-tight, permitting removal of the thermometer without lowering the liquid level or disturbing the transformer seal.

EYE-LEVEL MOUNTING

The eye-level thermometer is mounted at an easily readable and accessible height above ground level. A temperature detecting bulb inserted in the well at the top liquid level contains a liquid which expands or contracts with variations in the temperature. These changes are transmitted through capillary tubing to a Bourdon tube which operates the indicator shaft in the thermometer case.

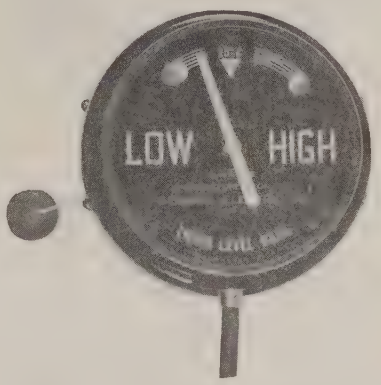


Fig. 2. Magnetic liquid-level gage with six-inch dial and alarm switch

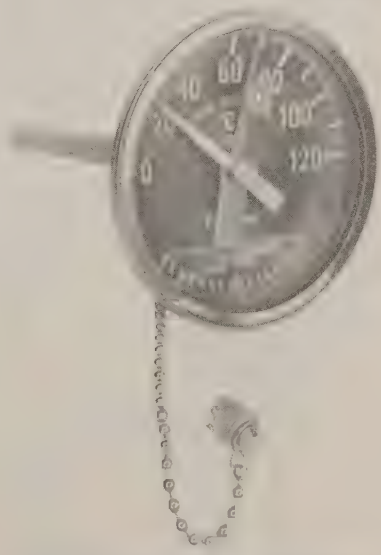


Fig. 4. Type AL liquid-temperature indicator

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

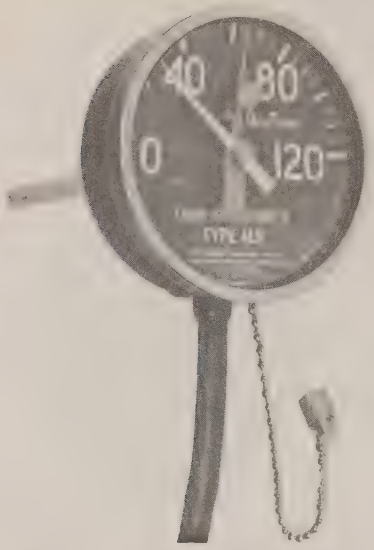
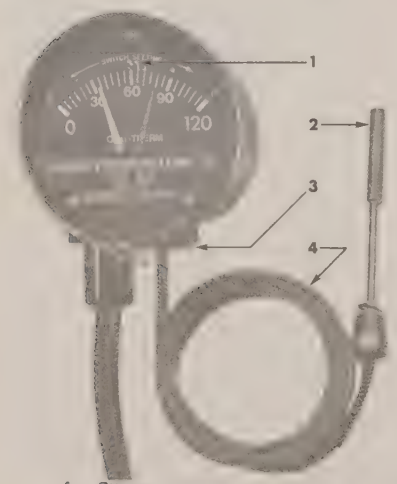


Fig. 5. Type ALR liquid-temperature indicator-relay, local, two- and three-switch

RESETTING MAXIMUM-READING POINTER

To reset the maximum reading pointer on local devices, remove the chained magnet from its recess, place it over the magnetic disk on the red pointer and slowly wipe across the face of the dial.

On the two-switch eye-level device, remove the chained cap at the bottom of the case and pull the projecting shaft (1, Fig. 6) until the red pointer rests against the white pointer. Replace the cap immediately to reseal the case. On the three-switch eye-level device, push the button (3, Fig. 7) on the bottom of the case.



1. SWITCH SETTING INDICATOR
2. TEMPERATURE DETECTOR
3. RESET BUTTON
4. CAPILLARY TUBING

Fig. 7. Type ALR liquid-temperature indicator-relay, eye-level, three-switch

SWITCHES

Type ALR thermometers are equipped with snap-action switches which are operated by cams on the indicating pointer shaft. In the standard two-switch device Switch No. 1 is normally used to control fans and Switch No. 2 is available for use in an alarm or control circuit. When fans are to be controlled by an ALR thermometer on transformers having a self-cooled/forced-air/forced-oil cooled rating, a three-switch device is provided. Switches Nos. 1 and 2 are used to control the transformer cooling equipment in two stages and Switch No. 3 is used for the alarm circuit.

Switch contacts are normally set to operate on rising temperatures as follows:

	2-Switch	3-Switch
Switch No. 1	65	60
Switch No. 2	90	65
Swicth No. 3	—	90

With falling temperatures the switches operate from 3C to 10C below these settings. Switch contacts are wired to a multiconductor cable and are color coded as shown in Fig. 8. Unless otherwise specified by the user, connections will be made to the normally-open contacts and leads from the normally-closed contacts will be taped up.

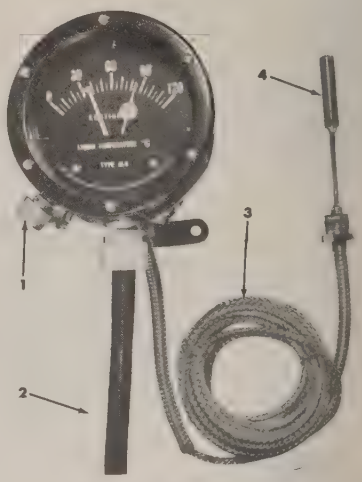
The switches in the thermometer are rated as follows:

ALR Device	Switch	Switch Ampere Rating A-C Volts			D-C Volts	
		125	250	480	125	250
Two-Switch, eye level	#1	15	15	15	.50	.25
	#2	5	5	—	.25	.20
All Others	All	15	15	15	.50	.25

When the thermometer switch contacts are used to control operation of the transformer cooling equipment, one or more separate "Hand-Auto" switches will be furnished for manual control and a magnetic contactor will also be included if the connected load exceeds the switch rating or if three-phase motors are employed. Refer to the transformer Connection Diagram for details.

INSTALLATION

The liquid temperature indicator is normally shipped in place. However, if it has been removed for shipment, its detector well will be closed with a threaded plug and the device will be identified by an appropriately marked copy of the shipping list. Remove the plug from the well and insert the detector bulb, making sure the gasket is in place before tightening the union nut. To install an eye-level device, mount the thermometer on the transformer as shown on the Outline drawing and then insert the bulb in the well. Attach the capillary tubing along the side of the transformer, coiling any excess and securing with the clips provided. The minimum safe bending radius for this tubing is 2 inches and undue bending and other abuses should be avoided. Make cable connections as indicated on the transformer Connection Diagram.



1. RESET-SHAFT CAP
2. CABLE
3. CAPILLARY TUBING
4. TEMPERATURE DETECTOR

Fig. 6. Type ALR liquid-temperature indicator-relay, eye-level, two-switch

TESTING

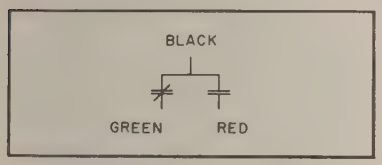
To check the operation of the thermometer or the temperature at which the switches operate, immerse its temperature-sensitive bulb in a container of liquid, along with an accurate centigrade thermometer and heat to a constant temperature. The reading of the liquid temperature indicator and the test thermometer should be within ± 2C of one another at any temperature on the dial. Switch operation can be checked by connecting a test light or alarm across the contacts and heating the bulb. Each switch should operate within ± 2C of its setting when compared with the indicator dial.

ADJUSTMENT

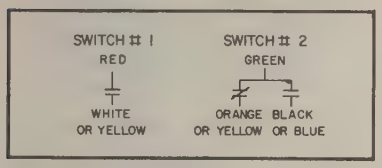
The instruments are factory calibrated and no changes are recommended. However, the following provisions have been made for making adjustments when necessary.

Local, Two-Switch

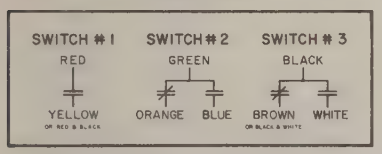
Slotted plugs in the top of the indicator case can be removed to provide access to the switch adjusting screws. After making the necessary adjustments, reseal the case using G-E compound A15A11A or Teflon tape on the plug threads. The adjusting screw for Switch No. 1 is on the right, facing the dial, and the Switch No. 2 adjustment is on



A. LIQUID LEVEL GAGE



B. TWO-SWITCH LIQUID TEMPERATURE INDICATOR



C. THREE-SWITCH LIQUID TEMPERATURE INDICATOR

NOTE — COLOR CODING OF ONE LEAD MAY DIFFER. UNLESS OTHERWISE SPECIFIED BY USER, CONNECTION WILL BE MADE TO THE NORMALLY OPEN CONTACTS AND LEADS FROM THE NORMALLY CLOSED CONTACTS WILL BE TAPED UP.

Fig. 8. Switch and cable connections for alarm contacts (when furnished)

the left. To raise the temperature setting, turn the No. 1 screw counterclockwise, and the No. 2 screw clockwise. Switch No. 1 can be adjusted through a range of 50C to 90C and Switch No. 2 from 65C to 110C.

Local, Three-Switch

Access for adjustment is through plugs in the case as with the two-switch instrument. Switches Nos. 1 and 2 have a common adjustment on the right and their settings are raised by turning the screw in a counterclockwise direction. The Switch No. 3 adjustment is on the left and is raised by turning the screw clockwise. Switch No. 1 has an adjustment range of 50C to 70C and Switch No. 2 is fixed at 5C above the setting of Switch No. 1. Switch No. 3 has a range of 70C to 100C and must be set at least 15C above Switch No. 2.

Eye-Level, Two-Switch

Provisions have been made at the rear of the case for adjusting the pointer with relation to the dial. To change switch settings, the glass face and nameplate must be removed. The set screws can then be loosened to permit adjustment of the switch operating cams on the indicating pointer shaft. Switch No. 1 can be adjusted through a range of 50C to 90C and Switch No. 2 has a range of 65C to 110C When replacing the glass, be sure the gasket is in place to seal the case.

Eye-Level, Three-Switch

To adjust the pointer with relation to the dial, remove the glass face and nameplate, loosen the screw at the base of the pointer, rotate the pointer as required, and retighten the screw. To change switch settings, move the switch setting indicator (1, Fig. 7) to a notch above the temperature indicated on the dial at which the switch is to operate. The switch adjustment range extends from 0 to 120C. When replacing the glass, be sure the gasket is in place to seal the case.

PRESSURE-RELIEF DEVICE

The mechanical, self-resetting, pressure-relief device, Fig. 9, is used on transformers to protect the tank against excessive internal pressures such as those which may accompany an arc under the insulating liquid. It is mounted on top of the transformer either on the main cover or on a man-hole cover and is also used occasionally on associated liquid-filled compartments. It consists primarily of a mounting flange, cover, two trigger springs and an O-ring gasket. A mechanical alarm is furnished with the device and upon request, an electrical alarm can also be furnished. Both types of alarms are normally removed for shipment and are to be installed before placing the transformer in service. See "Alarms."

OPERATION

The relief cover is used as the means of sensing pressure and tripping the device. The gas pressure within the transformer is applied over the entire area of the cover which in turn exerts a force against the two trigger springs. The load is applied along a line outside the spring column as shown in Fig. 10, tending to cause the springs to bend. No appreciable deflection will take place, however, until the load has been increased to a critical value. At this point the springs will begin to bow out and the force required for further bending becomes less as the deflection increases.

When the springs bow out, the cover opens to relieve the excessive gas pressures within the transformer. A bumper spring assembled on the center shaft cushions the opening shock and limits travel of the device. When the transformer pressure has returned to normal, the device will return to its original position, automatically resetting itself and resealing the transformer.

The transformer seal is maintained by an O-ring gasket between a vertical section of the mounting flange and the cover. A wider-than-normal gasket groove is used which permits the O-ring to roll rather than slide during the first part of the tripping action. By the time the O-ring reaches the top of the groove the trigger springs have bowed beyond their critical point and sufficient force is then readily available for sliding the cover over the gasket.

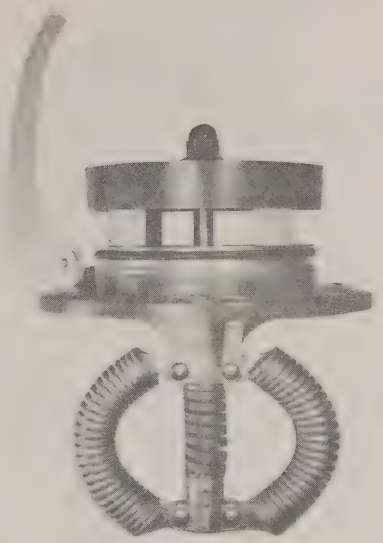


Fig. 9. Pressure-relief device blocked in open position with alarm vane vertical

The pressure at which the relief is set to operate is determined by the operating pressure of the transformer tank. The tank operating pressure is shown on the transformer nameplate and is also embossed on the cover of the relief device. Tanks operating up to 5 psi have reliefs set at approximately 8 psi, and 7.5 psi tanks have their reliefs set at approximately 11.5 psi.

ALARMS

The pressure relief device is provided with a mechanical alarm to give local indication of relief operation. The alarm consists of a plastic vane pivoted on a bracket and is normally removed for

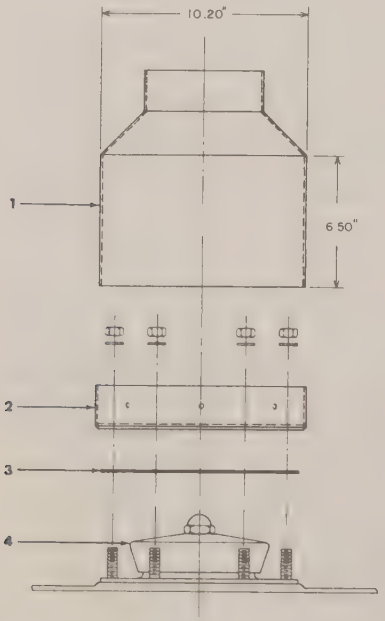
Fig. 10. Negative gradient spring

Fig. 11. Pressure-relief with mechanical and electrical alarm

shipment. To install the alarm, remove a nut from one of the relief mounting studs, place the bracket over this stud with the vane resting on top of the relief cover, and replace the nut. The vane will then remain in a *horizontal* position until the pressure-relief device operates, at which time the cover will push the vane into a *vertical* position.

Upon request, the plastic vane can be equipped with a mercury switch to provide remote indication of relief operation. The vane and a condulet fitting are then attached to a common mounting bracket which is removed for shipment and is to be installed as shown in Fig. 11. The switch is actuated by movement of the vane into the vertical position as the relief operates and is mounted to provide normally open contacts unless otherwise requested. Contacts are rated 4.5/2.25 amps at 110/220 volts a-c. and 3/1.5 amps at 125/250 volts d-c.

After tripping, the alarm vane must be reset in order to indicate subsequent operations.



1. Reducer
2. Adapter flange
3. Gasket
4. Pressure-relief device

Fig. 12. Exploded view of vent pipe accessories

GAS ABSORBERS AND VENT PIPES

If a Pyranol®-filled transformer is located in a poorly ventiliated indoor area, provisions should be made either to absorb or carry off any discharged gases. Refer to the National Electric Code for regulations pertaining to the indoor installation of Pyranol®-filled transformers.

Gas absorbers are designed for mounting directly on top of the pressure relief using the same mounting studs. Instructions for installing and filling the absorber are furnished with that device. A special adapter flange and gasket (2 and 3, Fig. 12) are available upon request for connecting vent pipes to the relief device. Order by drawing number 112A4035 G1 through the nearest apparatus Sales Office of the General Electric Company.

The reducer (1, Fig. 12) is to be made by the user and can be fabricated of sheet metal with a maximum outside diameter of 10.20" in order to fit the 10.25" inside diameter of the adapter. The height to the first bend must be at least 6.50" to clear the relief device cover when it opens and the other dimensions can be made as required.

PRESSURE-VACUUM GAGE

The presure-vacuum gage, Fig. 13, is of the compound type calibrated in pounds per square inch. Gage readings should vary as the transformer temperature changes and should normally indicate a positive pressure. (The instrument should not be expected to read accurately near the zero point.) When the transformer is de-energized or is operating under light or no-load conditions in a low ambient temperature, the gage may indicate a vacuum within the tank. A lack of any change in reading with changes in temperature is an indication of a leak in the transformer seal and should be investigated.

PRESSURE-VACUUM BLEEDER

Oil-filled, sealed-tank transformers are normally equipped with a pressure-vacuum bleeder. The bleeder, Fig. 14, is used on these units to maintain the internal tank pressure or vacuum within the maximum operating limits shown on the transformer nameplate. When load conditions and/or changes in ambient temperature cause the pressure or vacuum to become excessive, the device will automatically bleed air into or out of the gas space, preventing undue stress on the transformer tank. It is seldom required to operate, however, and serves primarily as a safety device.

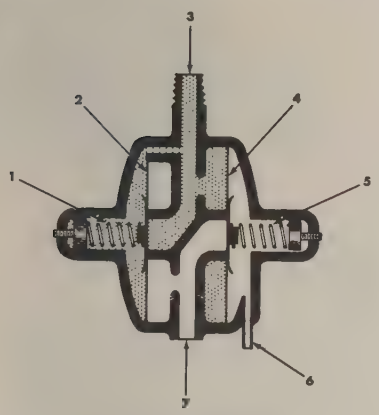
Fig. 13. Pressure-vacuum gage

OPERATION

Fig. 15 is a *multi-section view* showing the internal arrangement of the bleeder in *schematic form*. If a pressure exists in the transformer gas space, the pressure in the chamber to the left of diaphragm (4) will be greater than the atmospheric pressure in the chamber to its right. When the difference becomes great enough, spring (5) will be compressed permitting air from the transformer to bleed out through vent (6). If a vacuum exists, the atmospheric pressure in the chamber to the right of diaphragm (2) will be greater than the transformer pressure in the chamber to its left. When the difference becomes great enough, spring (1) will be compressed, permitting air to bleed into the transformer through breather port (7).

The pipe nipple and plug (Fig. 14) can be interchanged to permit installation of the bleeder from either the top or bottom, depending upon the application. If the device is ever removed from the transformer, use G-E compound A15A11A or Teflon tape on the threads when replacing and make sure

Fig. 14. Pressure - vacuum bleeder



1. Spring
2. Vacuum diaphragm
3. Transformer coupling
4. Pressure diaphragm
5. Spring
6. Equalizer vent
7. Breather port

Fig. 15. Schematic view of pressure-vacuum bleeder

the vent pipes face downward to prevent entrance of water.

The bleeder is factory calibrated to function at the operating pressures shown on the transformer nameplate and no changes should be made in these settings.

WEDGE-TYPE TAP CHANGER

Wedge-type tap changers provide a means of changing the voltage ratio of a de-energized transformer without breaking the transformer seal. Several different sizes are used, depending upon the current and voltage requirements of the circuit in which they are applied. They are shipped in place and are set on the position corresponding to the rated voltage shown on the transformer nameplate unless otherwise requested by the user.

Tap leads from the transformer windings are connected to a circular group of nickel-plated copper rods which are held together between two insulating heads. Fig. 16 shows a typical tap changer having the most common rod diameter and spacing arrangement. A wedge in the middle can be moved by a crankshaft to wedge between any two adjacent rods. A spring between the wedge and crankshaft maintains a high-pressure line contact between current-carrying components.

When the crankshaft is turned to move the wedge from one operating position to another, pressure is gradually reduced on the spring and the wedge is withdrawn from between rods. A U-shaped guide on the opposite side then pivots the wedge around to the next set of rods. As the crankshaft continues to turn, pressure is again applied to the spring and the wedge is forced into position with a wiping action, insuring positive contact.

Either of two different types of drive mechanisms may be furnished, depending on the torque required to drive a particular set of tap changers. The hex-head drive mechanism (Fig. 17A) is used in the majority of applications. In cases where the required driving torque exceeds the capability of this mechanism, the folding-handle drive (Fig. 17B) is furnished. The drive is normally located on the sidewall of the transformer and is connected through an insulator to the crankshaft of the tap changer.

The cap covering the mechanism is gasketed to the mounting flange and a pair of O-ring gaskets is used between the mounting flange and drive shaft to maintain the transformer seal. One of the screws used to hold the cap in place has an oversize head with a hole in it for padlocking if desired. When requested, provisions can also be included for interlocking with the primary circuit breaker (or high-voltage disconnect switch) as explained under "Interlocks." Position indication is provided by an arrow on the mounting flange and a corresponding number on the cap.

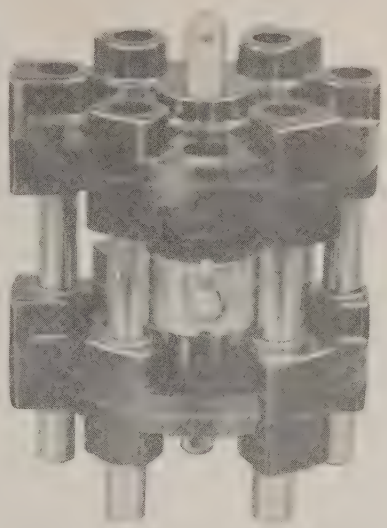
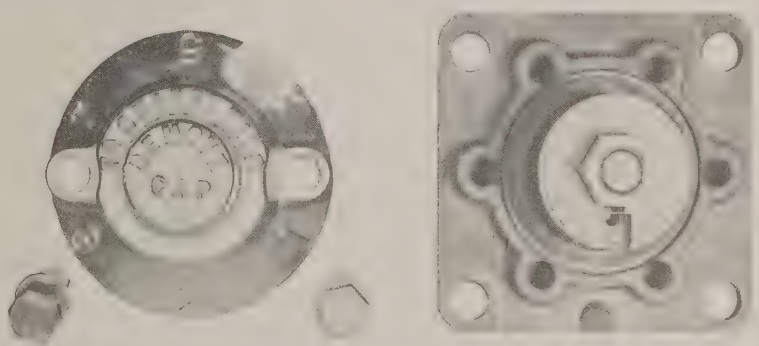


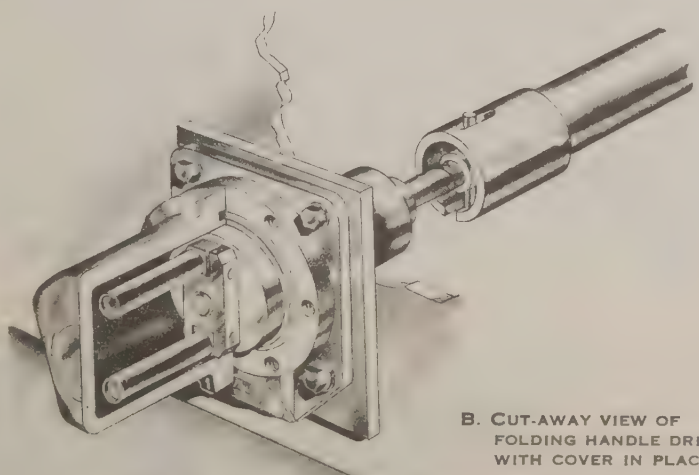
Fig. 16. Typical wedge-type tap changer

OPERATION

CAUTION! The tap changer must not be operated while the transformer is energized. Serious personal injury and/

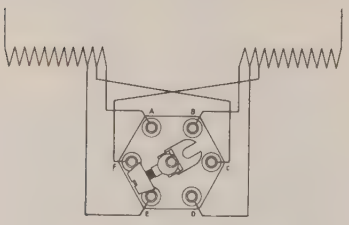


A. Operating mechanism with cover removed to show hex-head drive



B. Cut-away view of folding handle drive, with cover in place

Fig. 17. Tap changer drive mechanism



HIGH VOLTAGE CONNECTIONS LINES ON			
VOLTS (PERCENT)		DIAL POS	TAP CHANGER CONNECTS
105		1	A TO B
102.5		2	B TO C
100		3	C TO D
97.5		4	D TO E
95		5	E TO F

Fig. 18. Typical connection of a wedge-type tap changer

or damage to the transformer may result if this is attempted.

Fig. 18 shows a typical connection arrangement for a five-position wedge-type tap changer having two steps above and two steps below the rated voltage of the transformer. A table on the transformer nameplate gives the actual voltage and current rating for each tap position.

To change taps, de-energize the transformer and remove the tap-changer cover or cap. With the cover removed, the tap position can then be observed through a slot in the indicator cams. Rotate the mechanism using a wrench on the hex-head drive or the folding handle when the folding handle drive is furnished. Note that although the drive mechanism can be turned continuously in either direction, placing the tap changer in a number of different positions, *only those operating positions shown on the transformer nameplate are to be used.*

After the desired change has been made, make sure that the cover gasket is in good condition, replace the cover and bolt in place. The cover is designed so that it cannot be seated properly until the slots in the two indicator cams coincide, or until the operating handles have been folded back into the indicator slots. This serves to prevent the cover from being replaced until the tap changer is on position and also aligns the appropriate tap position number on the cover with an arrow on the mounting flange.

INTERLOCKS

Upon request, the operating mechanism can be equipped with a key-operated, plunger-type lock to provide a mechanical interlock with the circuit breaker (or disconnect switch) feeding the transformer. See Fig. 19. The key for this lock is normally held in a similar lock on the primary circuit breaker and can be removed only by opening the breaker and locking it open. This de-energizes the transformer and permits the key to be removed and used to unlock the tap changer.

To place the transformer back in service after the desired tap change has been made, lock the tap changer in position, remove the key, and unlock and reclose the primary circuit breaker.

NOTE: A duplicate key is furnished with the transformer. This key is for emergency use only and should be removed from the operating area to insure the effectiveness of the interlock system.

REMOVING AND REASSEMBLING

If it becomes necessary to disconnect or remove a tap-changer drive mechanism it should be placed on position 1 before removal in order to facilitate reassembly. To remove the drive mechanism, unbolt the flange and lift the device out as an assembly. Note that drive mechanisms are not interchangeable! When two or more are removed at the same time, care should be taken to reassemble them in the same location from which they were removed.

When replacing, see that the tap changer and the drive mechanism are both on position 1. The tap changer is on position 1 when the wedge bridges

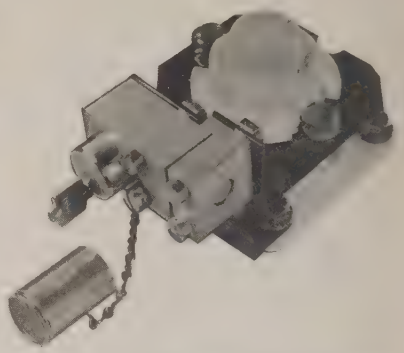


Fig. 19. Key interlock for hex-head drive tap changer

tap leads A and B and the index marks on the drive shaft and support structure are in line with one another. To reassemble, place the drive shaft through the opening in the mounting flange and slide the coupling over the tap-changer shaft. The slotted end of the coupling should engage a pin in the tap-changer shaft without difficulty if both mechanisms are in the proper position.

After reassembling, check to see that the wedge seats itself properly in each position by observing the torque required to turn the drive mechanism in each direction. The mechanism will be at the center of a high torque region when the wedge is properly seated. If the device was correctly reassembled, the position indicator should accurately show the various positions.

TESTING

Before placing a transformer in service, test the tap changer to determine that the positions are correct and that the steps progress in accordance with the transformer nameplate. To do this, apply a low voltage to one winding (normally the high-voltage) and measure the voltage on the other winding for each tap-changer position. *CAUTION: The turns ratio must be taken into consideration when making this test, as voltages endangering the operating personnel may be present.*

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

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Load Tap Changer

TYPE LRT-72

INTRODUCTION

Load-tap-changing equipment, Type LRT-72, is used to change the turns ratio of transformer windings under load. Automatic controls operate the motor-driven tap changer to maintain a constant voltage at the load center as the transformer input voltage fluctuates or as load conditions vary.

DESCRIPTION

The load-tap-changing equipment is assembled in two separate compartments as shown in Fig. 1. The upper, oil-filled compartment is bolted to the sidewall of the transformer and contains the tap selector, motor, gears, reversing-transfer switch, limit switches, etc. The lower, air-filled compartment, is bolted to the bottom of the oil compartment and contains the automatic controls.

Transformer accessories including the liquid-level gage, pressure-vacuum gage, liquid temperature indicator (and winding temperature equipment when required) are all mounted in a "control center" group on top of the oil compartment. Leads from devices having alarm contacts are wired down to terminal strips in the air compartment.

TAP SELECTOR

The tap selector, shown in Figs. 2 and 3, consists of three dial type switches. Each switch has nine stationary contacts which are connected to taps in the transformer winding. The contacts are mounted on an insulating panel in a circle around two concentric slip rings. The two movable contact fingers for each switch are mounted as an assembly on the main rotor shaft, which extends through all three phases of the tap selector, and each finger makes contact with its own slip ring. The two fingers move together, stopping either with both on the same contact or with one on each of two adjacent contacts. Connections from the tap selector to the interior of the transformer are made through bushings in an oil-tight insulating panel as shown in Fig. 4.

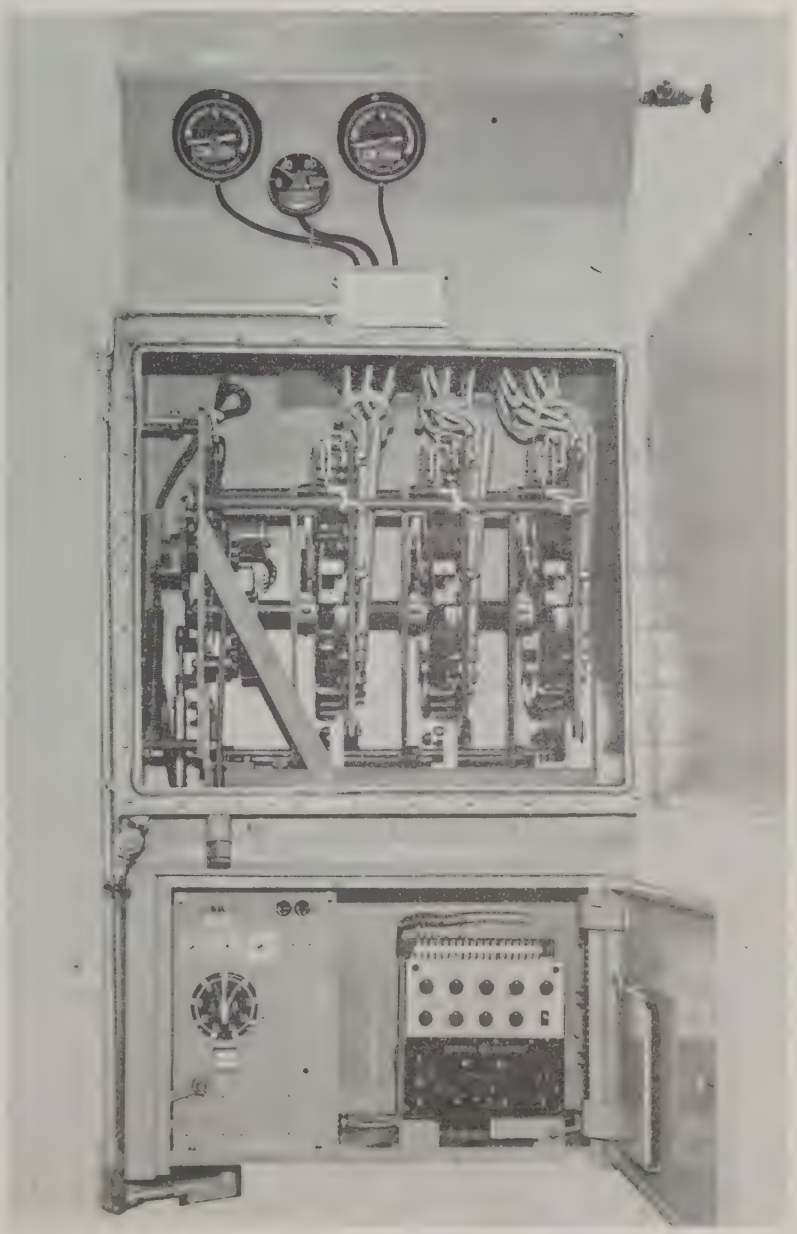
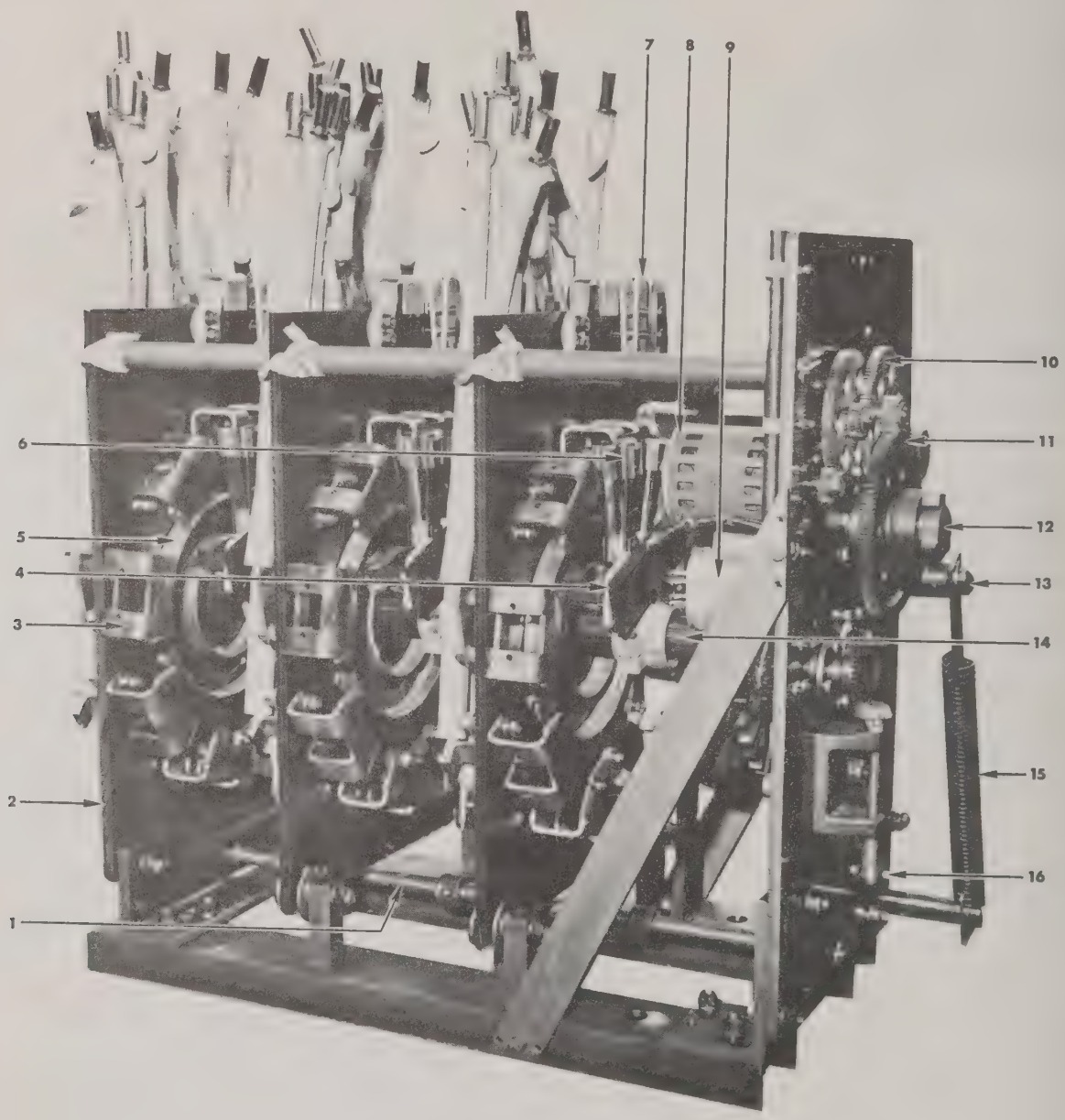


Fig. 1. Type LRT-72 load tap changer

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC



1. Operating shaft for reversing-transfer switch
2. Insulating panel
3. Stationary contact
4. Movable contact assembly
5. Slip rings
6. Movable contact fingers
7. Reversing-transfer switch
8. Motor
9. Motor capacitor
10. Reduction gears
11. Winding gear (loose on shaft)
12. Drive shaft
13. Crank
14. Main rotor shaft
15. Drive spring
16. Position-indicator drive shaft

Fig. 2. Tap selector

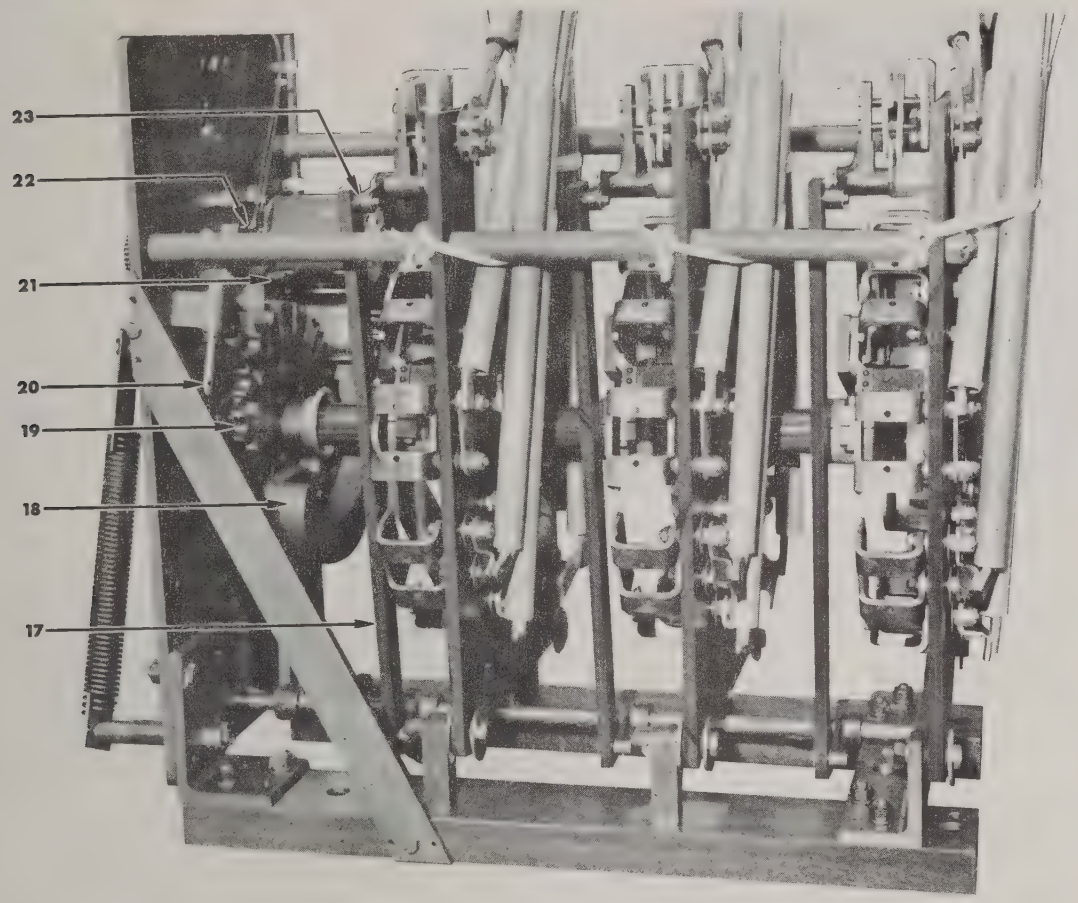
At the beginning of each tap change a spring is elongated by a motor acting through several reduction gears and a crank. As the crank is driven beyond dead center at the top of its stroke, the energy which has been stored in the spring is released to accelerate the rotor shaft Geneva gear and produce a change of taps. A counterweight on the Geneva gear smooths out the switch movement to minimize contact bounce on reclosing.

MOTOR

The tap selector motor is designed to operate submerged in oil and is rated as follows: 1/20 hp, 1600 rpm, 115 volts, 60 cycles, single phase.

REVERSING-TRANSFER SWITCH

Each of the three dial-type tap-selector switches is provided with a separate, single-pole, double-throw switch which is used to double the number of available tap positions as explained under "Operation." These three reversing-transfer switches are mounted at the



17. Insulating rod for reversing-transfer switch
18. Counterweight
19. Geneva gear
20. Connection for hand crank drive
21. Geneva gear driving pin
22. Operation counter switch
23. Crank for reversing-transfer switch

Fig. 3. Tap selector

top of the tap selector assembly (see Fig. 5) and are operated by a boss on the rotor shaft Geneva gear, acting through a Geneva sector, lever arms and connecting rods.

OPERATING LIMITS

When the tap selector moves to either of its maxmium positions, a limit switch opens the motor circuit to prevent any further movement in the same direction. If, for any reason, the motor should continue to run, a mechanical limit just beyond the electrical limit insures a positive stop.

MANUAL OPERATION

Provisions for manual operation of the load tap changer consist of a crank-shaft coupling located just above the door handle and a hand crank stored inside the air compartment. Removal of the hex-head plug in the coupling will allow the spring loaded drive shaft to extend outward and engage a clutch mechanism. The hand crank can then be used to change taps. (It may be necessary to rotate the shaft slightly to properly engage the clutch.) Approximately 6½ turns of the crank are required to move the tap selector switch one step. After the desired tap change has been made, replace the hex-head plug to disengage the clutch mechanism and provide a positive oil seal on the switch compartment. NOTE—Removing the hand crank from its mounting bracket operates an interlock which de-energizes the motor circuit. After changing taps manually, the crank must be replaced on its bracket before the motor can be operated.

POSITION INDICATOR AND OPERATION COUNTER

The position of the tap selector is shown by a dial type indicator in the control compartment, see Fig. 1. Drag fingers on the face of the indicator show the range through which taps have been changed since the fingers were last reset. The fingers can be reset at any time by depressing the lever behind the right-hand edge of the dial.

Each movement of the switch is recorded by an electric operation counter. The counter is located on the panel directly below the position indicator and is controlled by a snap-action switch mounted on the tap selector switch in the oil compartment.

CONTROL EQUIPMENT

The automatic controls which govern operation of the load tap changer are mounted on two main panels in the air box (see Fig. 1) and when required, auxiliary components can be installed on a third panel at the rear of the compartment. Access to the rear of the compartment can be obtained by lowering the left-hand panel or by swinging the right-hand panel on its hinges. The left-hand panel can be laid flat in the bottom of the compartment without disconnecting the wiring by removing the four mounting bolts and uncoupling the

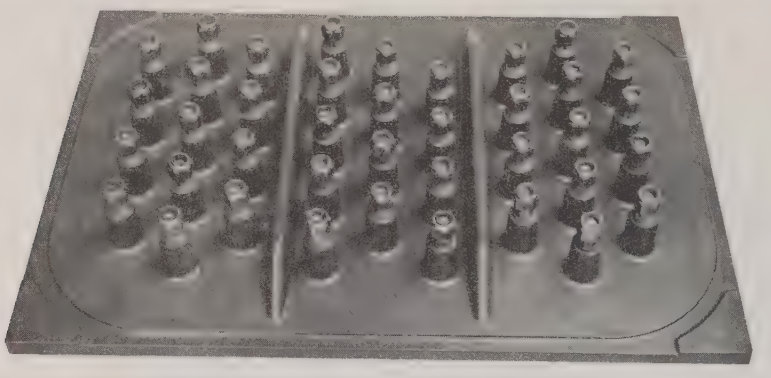


Fig. 4. Tap selector terminal board

position indicator drive shaft. When reassembling, make sure the position indicator is on the correct position.

INSTALLATION

The load-tap-changing equipment is shipped in place and can be made ready for operation by following the installation guide outlined below.

1. BREATHERS—Remove the two pipe caps used to seal the tap-selector compartment during shipment and install the breathers.

2. INSPECTION—Drain the oil from the tap-selector compartment and make the following inspection.

A. Check for loose or damaged parts.

B. Operate the tap selector through all positions with the hand crank and check for binding.

C. Operate through all positions by motor, using either a temporary or the permanent power supply, and check to see that the limit switches, position indicator and operations counter function properly.

Note: Insulating panels in the compartment can absorb moisture during prolonged exposure to the atmosphere. Periods exceeding 60 hours should be avoided since a drying cycle may then be required.

3. FILL COMPARTMENT — Check the dielectric strength of the oil and fill the tap selector compartment to the 25 C level as indicated on the liquid-level gage. *CAUTION*: Although in some cases the main transformer tank is designed to withstand full vacuum, the tap-selector compartment is *not!* If desired, the compartment may be filled under a partial vacuum not to exceed 5 psi.

4. CONNECTIONS — Refer to the transformer Connection Diagram for accessory wiring to the control compartment and to the Control Diagram for wiring and elementary diagrams of the automatic load-tap-changer control circuits. Several plugged holes are provided in the bottom of the compartment for making conduit connections.

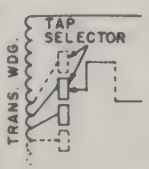
Make connections to the control power and potential supplies if these connections have not already been made. Note that the 120 volt potential supply for the automatic controls must be taken from the circuit to be regulated. For proper line-drop compensation, the potential supply and the current supply must be in phase on the basis of unity power-factor load current. When a reclosing relay is provided for the main circuit breaker feeding the transformer, refer to the notations on the Control Diagram for special connections to prevent initiation of a tap change under fault conditions.

5. MOTOR AND CONTROL DEVICES. Check the operation of the motor and all devices on the control panel at the lowest voltage anticipated. The equipment can not be expected to operate satisfactorily when the potential across terminals (M4-M6) drops below 95 volts. Adjust the controls as explained in separate instructions.

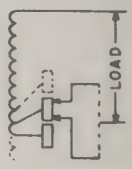
SWITCH OPERATION

The manner in which a tap change is made while the transformer is carrying a load can be more easily understood by referring to the schematic diagram and table on the transformer nameplate. The sequence of operations used to prevent open or short circuits, minimize arcing and obtain thirty-two steps is explained in the following paragraphs.

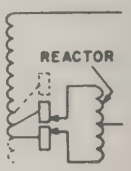
1. Tap leads from the transformer winding are connected to stationary contacts (nine per phase) on the tap selector. When the motor and spring operate the selector it will change taps to vary the transformer voltage ratio and thereby regulate the voltage.



2. Two movable contacts are used on the tap selector so that one can be moved to an adjacent tap while the other maintains the power circuit.

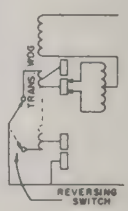


3. The movable contacts are connected together through a reactor to prevent excessive circulating current through a bridged section of the transformer winding. By designing the winding and reactor to carry the circulating current, the bridging position can be used as an intermediate operating position, thereby doubling the number of steps.

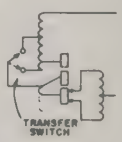


4. A two-position switch, integral with the tap selector, is used to double the number of steps again.

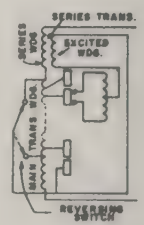
The switch can be used to *reverse* the polarity of the voltage taken from the tapped section, permitting the tapped section to be used twice—one time adding to and the other time subtracting from the voltage of the main winding, or—



It can be used to *transfer* another section of the main winding into or out of the circuit, also permitting the tapped section to be used twice — once by itself and once with additional turns in series with it.



5. The addition of a series transformer permits the use of the tap selector switch in circuits where the current to be interrupted would otherwise exceed the capability of the switch. Its series winding is placed in series with the load and voltage from the tapped section is impressed upon its excited winding. A reversing switch changes the polarity of the voltage applied to the excited winding, making it possible to add to or subtract from the voltage in the main transformer winding, thus regulating the output. With the tap changer on the middle or neutral position, zero voltage is impressed on the excited winding and the output voltage is neither raised or lowered.



DRIVE SEQUENCE

When either the manual or automatic

controls call for a change of position, a motor is energized which drives the tap selector through a series of gears, cranks, shafts, rods and levers. The sequence of operations can be traced as follows. Refer to Figs. 2, 3, and 5. Motor (8) operates through reduction gears (10) to turn winding gear (11) which is loose on its shaft. A boss on winding gear (11) engages crank (13), which begins to extend spring (15). As the motor continues to run, a lug on crank (13) engages the cam on shaft (12) which starts rotation of the Geneva gear driving pin (21). As crank (13) passes dead center at the top of its stroke, spring (15) rapidly rotates the crank, shaft, driving pin and Geneva gear (19) to advance the main rotor shaft (14) and movable contact fingers (6) one position. An extension of shaft (12) locks the Geneva gear in position except when a tap change is being made.

To operate reversing-transfer switch (7), a boss on Geneva gear (19) engages a Geneva sector which rotates shaft (1). Shaft (1) through rods (17) and cranks (23) operates the switch in each phase simultaneously. Driving spring (15) can also be elongated manually by using the hand crank. Turning the crank rotates a shaft which, through connection (20) and a set of bevel gears, turns winding gear (11) to stretch the spring just as the motor does.

MAINTENANCE

Check the condition and dielectric strength of the oil in the tap-selector compartment yearly and replace if necessary. Maintain the oil level as indicated by the oil gage. The weatherproof breathers on the oil compartment should be cleaned at intervals to assure proper venting of the gases produced by switch arcing. Lubricate the position-indicator gears as required.

INSPECTION OF TAP-SELECTOR CONTACTS

The tap-selecting switches break a certain amount of circulating and load current at each tap change. The tip of each contact has a piece of arc-resisting alloy brazed to it which provides exceptionally long life under normal loading conditions. When new, the movable contacts are 1¼" long, 1" wide, and 5/16" thick. Because the leading and trailing edges are beveled, the faces which wipe on the stationary contacts are 1¼" long by ½" wide. The alloy portion of new stationary contacts is 1¼" x ¼" x ¼".

It is recommended that the entire switch be inspected at the end of one year (or after 20,000 operations) and thereafter at five-year intervals (or every 100,000 operations). Do not dress or file the contact surfaces as this will merely remove useful metal and shorten their life. The arc-resisting alloy will continue to give satisfactory service until the movable contacts are reduced to a thin line or the stationary contacts have been worn back to the copper support. At this point, all of the contacts should be replaced.

Each time the tap-selector compartment is opened all surfaces of the rotor shafts, panels, and other insulating parts should be thoroughly cleaned of any carbonized oil particles deposited on them. Clean by washing with clean, dry transformer oil applied with dry, lint-free cloths.

RENEWAL PARTS

Replacement parts can be obtained by placing an order with the nearest Apparatus Sales Office of the General Electric Company. Be sure to include the transformer serial number and a description of the items involved. Stationary switch contacts can be ordered by catalog number 349A143G1 (27 required). Moving contact assembles can be ordered by 379C615G1 for switches with copper slip rings or by 379C616G1 for switches with silver plated slip rings (3 required in either case).

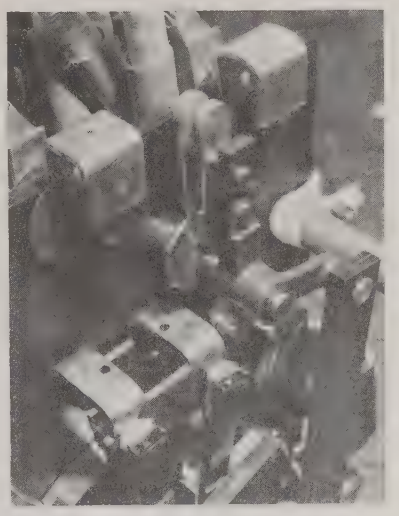


Fig. 5. Reversing-transfer switch (above), moving and stationary contacts (below)

After a new set of tap-selector switch contacts has been installed, or after any reassembly, operate the mechanism through all positions with the hand crank and observe alignment of the moving and stationary contacts. Make any adjustments required in order to produce total and positive contact of the two mating surfaces (4 to 7 pounds on each finger) on every position. Using manual controls, operate the mechanism by motor and check to see that it functions properly.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

Load-Tap-Changing Equipment

TYPE LR-65

INTRODUCTION

Load-tap-changing equipment, Type LR-65 is used to change the turns ratio of the transformer windings under load. The equipment is mounted on the transformer tank wall in two separate compartments as shown in Fig. 1. The upper compartment is oil-filled and contains the tap selector and contactor assembly. The lower compartment contains the motor drive assembly and its controls plus an accessory panel on the right-hand side for mounting terminal boards, various transformer accessories, and related components. Access to this panel is provided by a separate external door which opens from inside the compartment.

Control of the motor drive equipment may be either manual or automatic/manual, depending on the requirements of the installation, and can be located at the transformer and/or on a remote panel. When equipped with automatic controls a relatively constant voltage can be maintained automatically at some predetermined load center as the transformer input voltage fluctuates and as load conditions vary.

In the following text, numbers in parentheses refer to items in the various figures and symbols in italics refer to components shown in Fig. 5 and on the LTC Control Diagram. Note that the diagram shown in Fig. 5 is of a typical nature only and for complete details of any particular installation, the user is referred to the Control Diagram furnished with the transformer.

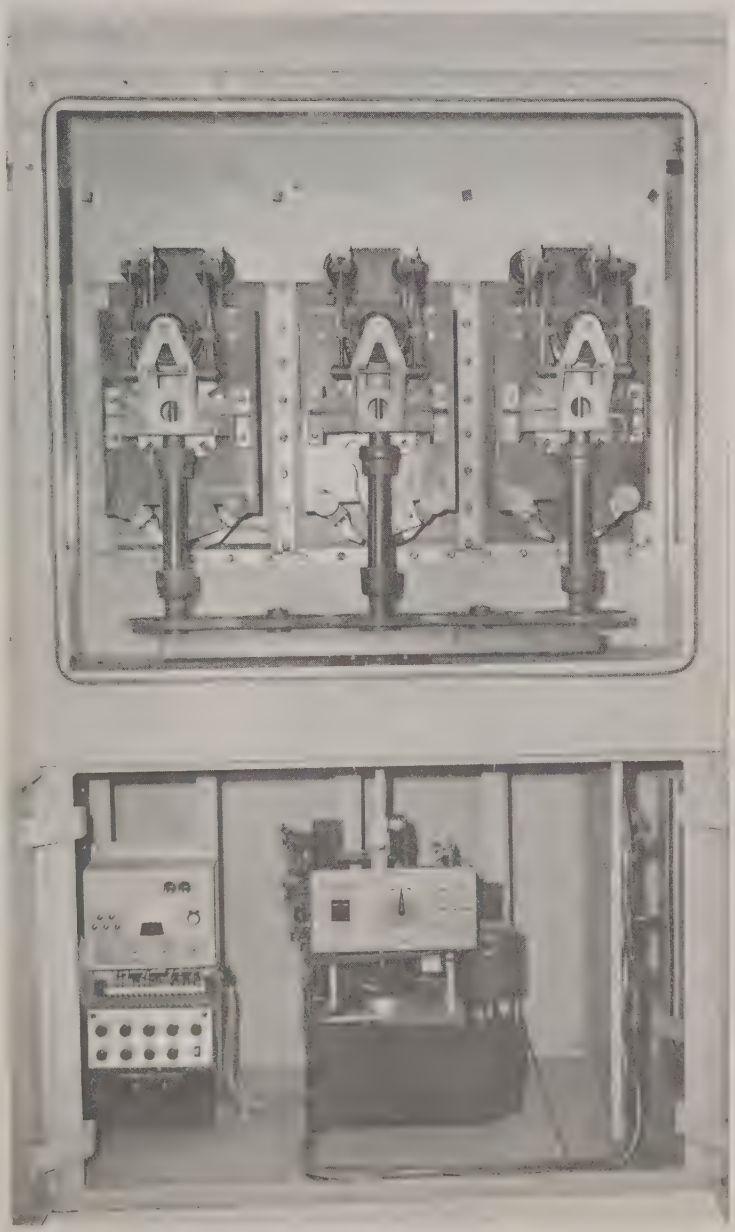


Fig. 1. Load-tap-changing equipment, Type LR-65

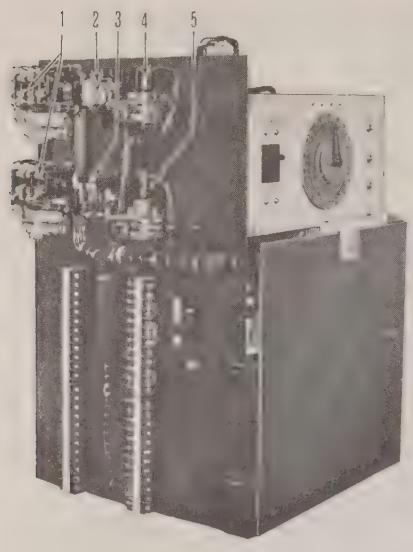
DESCRIPTION

MOTOR DRIVE

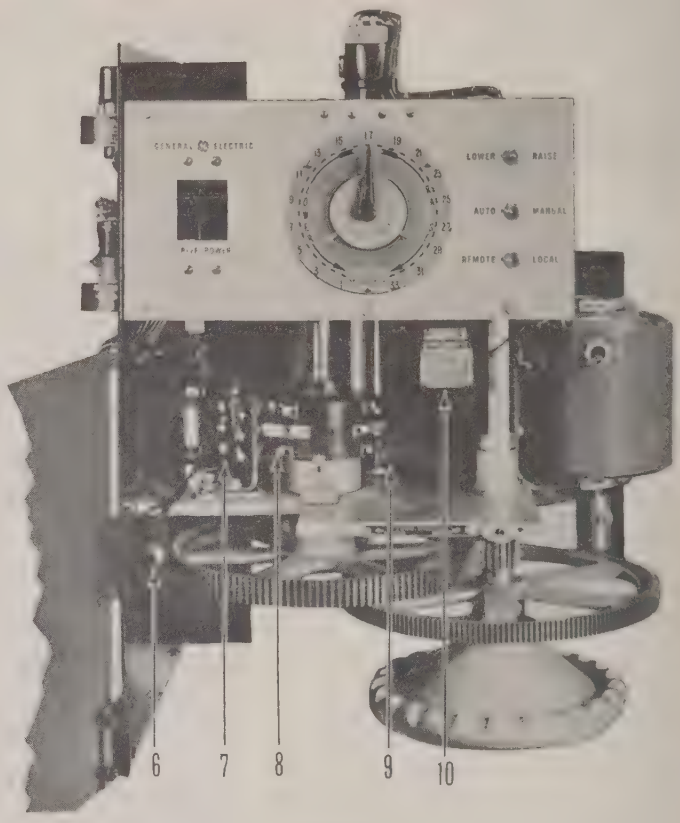
The load-tap-changer motor drive, Fig. 2, consists of the following main parts: a fractional horsepower motor, a set of reduction gears, a cam-type controller drum, auxiliary controls, and an operating panel containing drive power circuit breaker *8M*, the position indictor assembly, and raise/lower switch *CST*. When required, this panel may also contain auto-manual switch *43T* and remote-local switch *43TRL*.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

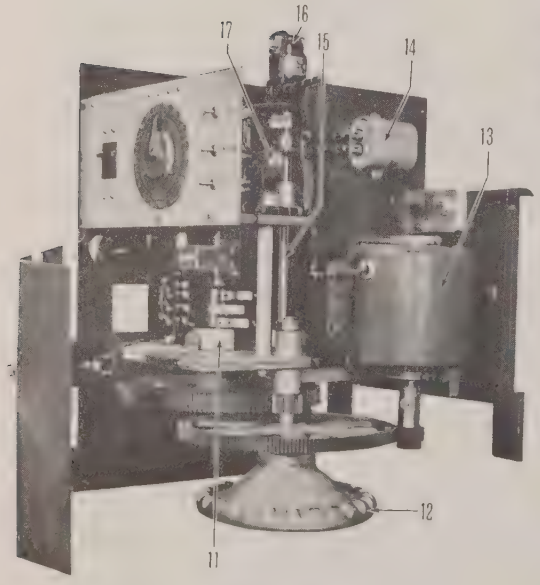
GENERAL ELECTRIC



LEFT SIDE



FRONT



RIGHT SIDE

1. MOTOR REVERSING RELAYS 84R AND 84L
2. AUXILIARY RELAY 84D FOR DYNAMIC BRAKING
3. AUXILIARY RELAY 84Y
4. TIME-DELAY RELAY 84X FOR DYNAMIC BRAKING
5. TIME-DELAY RELAY 66
6. MOTOR-DRIVE INTERLOCK SWITCH 841
7. CONTROLLER DRUM SWITCHES 33S
8. CONTROLLER DRUM CAMS
9. POSITIVE STOP LUG
10. OPERATION COUNTER OC
11. POSITIVE STOP CAM
12. HANDWHEEL
13. MOTOR 84
14. MOTOR CAPACITOR CAP
15. AUXILIARY SHAFT
16. SELSYN TRANSMITTER
17. INDICATOR SHAFT

Fig. 2. Motor drive assembly

Controller Drum and Dynamic Braking

The sequence of operations required to make a tap change is controlled by cams (8) on a controller drum mounted on the main output shaft. The operating motor turns this shaft through a series of reduction gears to drive the tap changer in the overhead compartment. The drum is provided with three cams, one above the other, and as the output shaft rotates, each cam moves to operate contacts of controller switch *33S* (7). Once a tap change has been initiated, these contacts control the operation of a number of relays and timers to insure the completion of the changing cycle.

The drum switching sequence also serves to stop the mechanism exactly on position at the end of each tap change through the use of a dynamic braking circuit. This method of stopping involves the application of a momentary d-c current across the motor windings at the proper time as explained more fully under "Operation."

The controller drum also provides a visual means of determining whether or not the tap selector and contactor assembly has stopped on position. A white line on the lower part of the drum should align itself with the adjacent ON-POSITION nameplate at the conclusion of each tap change if the motor drive is functioning properly.

Position Indicator and Operation Counter

The position indicator is attached to a shaft which is driven by a worm gear on the main output shaft. The gear ratio is such as to cause the indicating pointer to move through 320 degrees for the full range of tap changes. Numbers on the dial correspond to tap positions shown on the transformer nameplate and drag fingers show the extremes in operating positions since last reset. The fingers are held in a given position by friction and can be reset by pushing them around to coincide with the indicating pointer.

An operation counter *OC* (10) is mounted on a bracket beneath the control panel and can be observed through a window at the front of the mechanism. The counter is operated electrically through contacts *2-12* of controller switch *33S*. Periodic recordings of the counter readings are recommended as a means of determining when to conduct an inspection of the arcing contacts. See "Maintenance."

Limit Switches and Positive Stop

Snap-action limit switches are mounted behind the position indicator dial and their contacts are wired into the motor relay circuit. A trip lever on the position indicator shaft opens switch (84LS/L) at the maximum lower position, or switch (84LS/R) at the maximum raise position, to prevent electrical operation of the mechanism beyond either of these end positions.

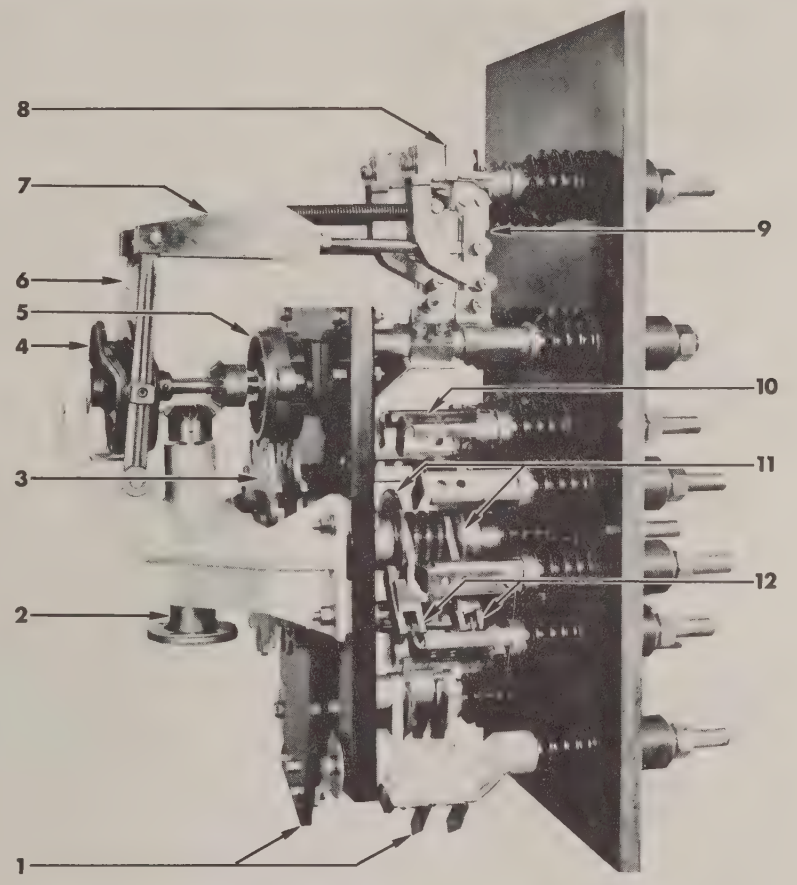
A mechanical limit is provided in addition to the electrical limits. A positive stop lug (9) is mounted at the lower end of an auxiliary shaft (15) and is equipped with a rubber cushion which acts as a shock absorber. The lug rotates to engage a stop cam (11) on the main output shaft at a point just slightly beyond the electrical limits, thus mechanically blocking any attempt to move the mechanism beyond the end positions.

TAP SELECTOR AND CONTACTOR

The tap selector and contactor assembly, Fig. 3, is driven through a set of bevel gears supported from a bracket at the front of the assembly. A vertical insulating coupling provides the necessary insulation to ground and connects the bevel gear drive shaft (2) through an oil seal to the motor drive mechanism in the lower compartment. When applied on a three-phase transformer, three of these assemblies are mounted side-by-side and a one-to-one ratio gear train is included at the bottom of the compartment to drive all three phases simultaneously. See Fig. 1.

Tap Selector

The tap selector consists of two movable contact arms (12) which rotate to connect with the stationary contacts (10). There are nine stationary contacts arranged in a circle and each is provided with two shelves, one for each of the two movable arms. The stationary contacts are bolted to bushings which extend through an insulating mounting panel and winding tap leads are connected to these studs at the back of the panel. When bolted in place, the mounting panel seals an opening at the rear of the tap selector and contactor compartment, thus separating it from the remainder of the transformer.



1. Reversing (or transfer) switch
2. Drive shaft
3. Geneva gears
4. Scroll cam
5. Geneva gear driver
6. Lever
7. Push rod
8. Arcing contacts
9. Main contacts
10. Stationary contacts
11. Collector rings
12. Movable contact arms

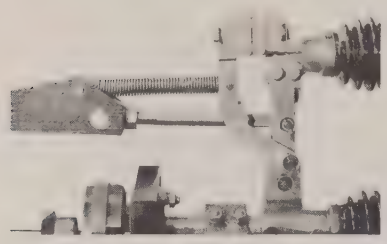
Fig. 3. Tap selector and contactor assembly

The movable contact arms are mounted on two concentric drive shafts and each makes sliding contact with a collector ring (11). The two arms are insulated from one another and operate independently to make contact with either the same or adjacent stationary contacts as required. A Geneva gear (3) is mounted at the end of each drive shaft and these two gears are actuated by pins on a double Geneva gear driver (5). The arrangement is such that the two shafts and their contacts are locked in position except during tap changes at which time they are rotated in an alternating sequence by the double driver. With the two arms on the same stationary contact, a one-half revolution of the main drive shaft causes one arm to move to the next adjacent contact, and on completion of the revolution the second arm is moved to this same contact.

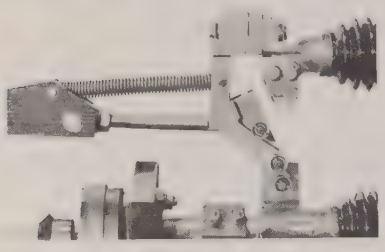
Contactor

The contactor is mounted above the tap selector on the same insulating panel and a bracket at the front of the assembly supports the contactor operating mechanism. Rollers riding in the groove of a scroll cam (4) move two levers (6) which, through two push rods (7), open and close the contacts.

The contactor consists of two units, each combining main current-carrying



A. MAIN AND ARCING CONTACTS CLOSED



B. MAIN CONTACTS OPEN, ARCING CONTACTS CLOSED

C. MAIN AND ARCING CONTACTS OPEN

Fig. 4. Contactor operating sequence

contacts (9) of the double-blade, pinch-finger type and large arcing contacts (8) made of a tungsten-base material. These contacts are connected in parallel. Fig. 4 shows the opening sequence of the contactor as first (B) the main contacts open and then (C) the arcing contacts open. In closing, the arcing contacts close in advance of the main contacts. Thus all arcing takes place at the arcing contacts. The main pinch-finger contacts may show very slight pitting at the edges, which results from transferring the load current into the higher resistance arcing contacts. However, this pitting does not detract from the current carrying function, and it is not expected that these contacts will require servicing during the life of the transformer.

Reversing (or Transfer) Switch

A reversing (or transfer) switch (1), when used, is mounted on the lower part of the insulating plate at the front of the tap selector. The switch is of the single-pole, double-throw type and is actuated by an insulating arm and a boss on the rear Geneva gear. This switch is locked in the closed position on one side during all operations of the tap selector until the ninth tap is reached. At this point the switch closes on the opposite side and is locked in this position while the tap selector is completing the second revolution.

INSTALLATION

The load-tap-changing equipment is shipped in place and can be made ready for operation by following the installation guide outlined below.

1. BREATHERS—Remove the two pipe caps used to seal the tap-selector compartment during shipment and install the breathers.

2. INSPECTION—Drain the oil from the tap-selector compartment and make the following inspection.

   A. Check for loose or damaged parts.

   B. Operate the tap selector with the handwheel and check for binding. See "Handwheel Operation."

   C. Operate through all positions electrically by means of the manual-control switch and check to see that the limit switches, position indicator, and operation counter function properly.

   D. Make sure the mechanism stops on position by checking to see that the white line on the controller drum lines up with the ON-POSITION nameplate.

   E. If an alignment error exists or if the limit switches require adjustment, refer to the procedures outlined under "Maintenance."

Note: Insulating panels in the compartment can absorb moisture during prolonged exposure to the atmosphere. Periods exceeding 60 hours should, therefore, be avoided since a drying cycle may then be required.

3. FILL COMPARTMENT—Check the dielectric strength of the oil and fill the tap selector compartment to the 25 C level as indicated on the liquid-level gage. *CAUTION*: Although in some cases the main transformer tank is designed to withstand full vacuum, the tap-selector compartment is *not!* If desired, the compartment may be filled under a partial vacuum not to exceed 5 psi.

4. CONNECTIONS—Refer to the transformer Connection Diagram for accessory wiring in the control compartment and to the LTC Control Diagram for wiring and elementary diagrams of the load-tap-changer control circuits. A removable drill-plate is provided in the bottom of the compartment for making conduit connections.

5. AUTOMATIC CONTROLS—When provided with automatic controls, note that the 120 volt potential supply must be taken from the circuit to be regulated. For proper line-drop compensation, the potential supply and the current supply must be in phase on the basis of unity power-factor load current. When a reclosing relay is provided for the main circuit breaker feeding the transformer, refer to the notations on the Control Diagram for special connections to prevent initiation of a tap change under fault conditions.

OPERATION

MOTOR DRIVE

A tap change can be initiated by raise/lower switch *CST* on the control panel or by the automatic control devices when furnished. When changing taps by means of the manual control switch, hold it in contact for a fraction of a second to allow time for the seal-in circuit to establish itself. Once a tap change has been initiated, control of the mechanism is taken over by the controller drum and its related cams and switches *33S*. The operating sequence of these switches is illustrated in the typical motor-drive control diagram of Fig. 5.

Assuming that a change of taps has been called for in the raise direction, the motor drive equipment will function as follows:

1. Motor raise relay *84R* is energized through normally closed contacts *1-2* of relay *84L* and limit switch *84LS/R*.

2. Once relay *84R* has been energized, the following occurs:

   a. Contacts *1-2* open to lock out the corresponding lower circuit.

   b. Contacts *3-4* close to seal in relay *84R* through contacts *3-13* (bottom cam) of *33S*.

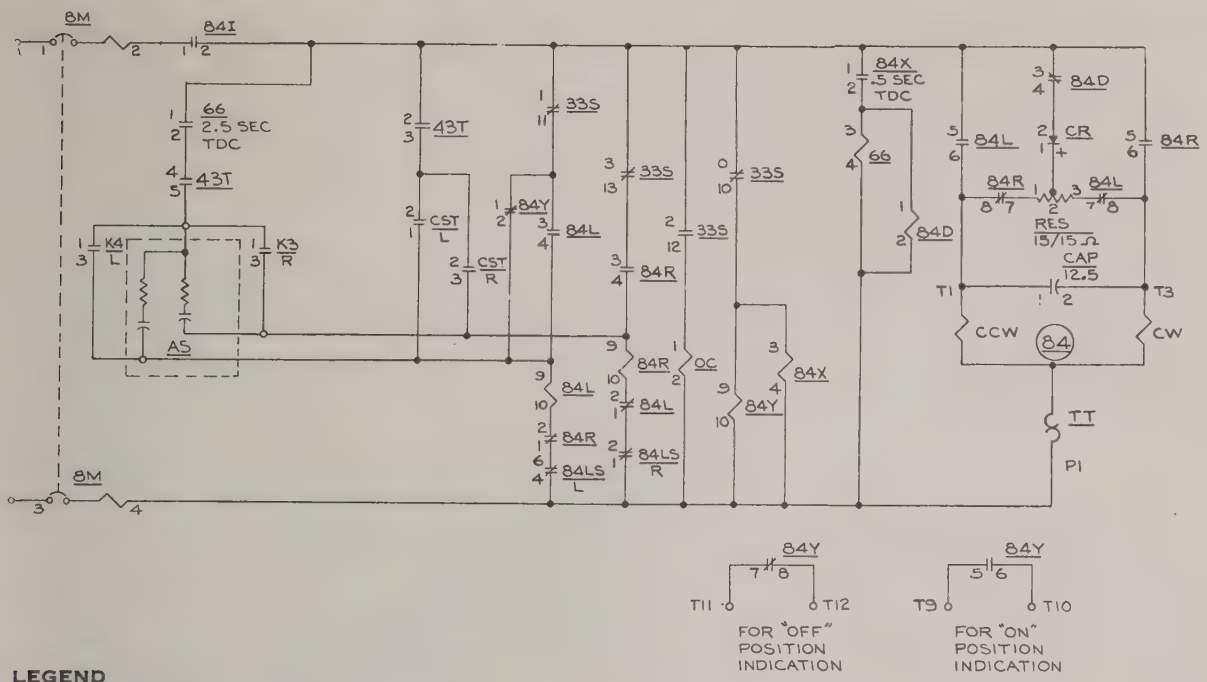
   c. Contacts *5-6* close to energize motor *84*.

   d. Contacts *7-8* open to prevent dynamic braking power from being applied to the motor while it is being energized through relay *84R*.

3. As the mechanism moves off position, contacts *0-10* (center cam) of *33S* open to de-energize auxiliary relay *84Y*.

   a. Contacts *1-2* of *84Y* then close to bypass the seal-in contacts for motor lower relay *84L*. This action serves to protect the mechanism from remaining off position (see "Off-Position Operation") in the event of temporary loss of control power.

   If the power supply should fail, relay *84R* would drop out, los-



LEGEND

8M	DRIVE POWER CIRCUIT BREAKER
33S	SWITCH CONTACTS ON CONTROLLER DRUM
43T	TRANSFER SWITCH AT TRANSFORMER (AUTOMATIC, MANUAL)
66	TIME DELAY RELAY
84	OPERATING MOTOR
84D	AUXILIARY RELAY FOR DYNAMIC BRAKING
84I	MOTOR DRIVE INTERLOCK SWITCH
84R,84L	MOTOR REVERSING RELAYS
84X	TIME DELAY RELAY FOR DYNAMIC BRAKING
84Y	AUXILIARY RELAY
AS	ARC SUPPRESSOR ON AUTOMATIC CONTROL
CR	RECTIFIER
CST	CONTROL SWITCH AT TRANSFORMER (RAISE, OFF, LOWER)
L	LOWER
LS	LIMIT SWITCH
OC	OPERATION COUNTER
R	RAISE
TDC	TIME DELAY CLOSING
TT	MANUAL RESET THERMOTECTOR IN MOTOR
K3/R,K4/L	RELAYS ON AUTOMATIC CONTROL

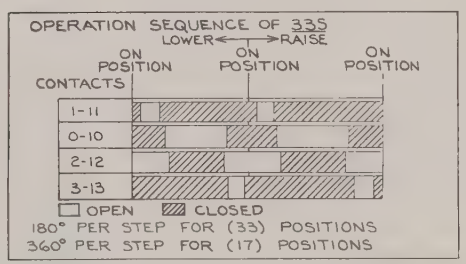


Fig. 5. Typical motor drive Control Diagram

ing its seal-in and preventing any further movement in the raise direction. However, at the same time it would also reclose its contacts *1-2*, thereby completing the lower circuit and allowing the mechanism to return to the next lower operating position upon return of power. At that point the control would revert to normal and the mechanism would then be free to move again as required.

b. Two additional sets of contacts on relay *84Y* can be connected by the user to provide remote on- and off-position indication as shown on the Control Diagram.

4. Contacts *0-10* of *33S* also de-energize time delay relay *84X* which, through its contacts *1-2*, de-energizes relays *66* and *84D*.

a. Time delay relay *66* is included only when automatic controls are provided. Its contacts *1-2* introduce a time delay as the mechanism reaches each operating position, thus allowing time for the automatic controls to determine whether or not an additional change is required.

b. Contacts *3-4* of *84D* close to prepare for the dynamic braking operation to follow.

5. Contacts *2-12* (center cam) of *33S* close and open during each tap change to provide a pulse for operation counter *OC*.

6. When the mechanism approaches the next operating position controller *33S* contacts *0-10* reclose to:

a. Energize relay *84Y* and defeat the off-position emergency runback circuit.

b. Energize relay *84X* to initiate a time delay for the automatic controls and the dynamic braking circuit.

7. At the same time, controller contacts *3-13* open to drop out relay *84R*, thus removing a-c power from the motor. Contacts *3-4* of *84D* maintain a circuit through rectifier *CR* and a resistor to pass d-c (half-wave rectified a-c) through both motor windings, effecting dynamic braking. After approximately 0.5 seconds contacts *1-2* of *84X* close to pick up *84D* and remove the d-c power from the motor.

8. The sequence of operations for changing taps in the lower direction is practically identical to those outlined for raising except that the change is initiated through relay *84L*.

Handwheel Operation

The motor drive mechanism is provided with a handwheel to permit manual operation of the load-tap-changing equipment before placing it in service or when necessary to inspect or replace the arcing contacts. It can also be used at any time the motor is inoperative. The handwheel (12, Fig. 2) is located at the bottom of the motor-drive behind a hinged panel and is connected through

spur gears to the lower end of the output drive shaft. When the panel is opened, electrical interlock *841* (6, Fig. 2) breaks the circuit to the motor-drive. As an added precaution, open the DRIVE POWER circuit breaker on the operator's control panel before turning the handwheel.

When checking the load-tap-changer operation with the handwheel, examine carefully for any binding or other abnormal conditions. If the mechanism should turn very hard or apparently stall, investigate and correct the trouble. The handwheel will turn with considerable stiffness at two points during each revolution of the main output shaft. This is a normal condition, however, and is due to the force necessary to compress the contactor springs.

The position indicator will show the tap position and also the direction in which taps are being changed. Watch the indicator and the ON-POSITION mark on the controller drum to be sure the mechanism is stopped on an operating position. The mechanical stop becomes effective on the end positions to prevent further hand operation beyond limiting positions if such operation is attempted.

If it should become necessary to operate the mechanism by hand while the transformer is loaded, for example due to loss of motor supply voltage, the operation should be performed at a uniform speed and as rapidly as possible. This will minimize burning of the contacts and prolong their life.

TAP SELECTOR AND CONTACTOR

Each contactor is electrically connected in series with one of the movable contacts of the tap selector. They are also mechanically interconnected by means of the scroll cam and Geneva gear driver in such a manner that the contactor in each half of the circuit always opens before its corresponding tap selector begins to move, thus preventing the tap selector from interrupting current.

The sequence of operations and the methods of connecting the tap selectors and contactors to the transformer windings are described in the following paragraphs and corresponding steps shown in Fig. 6. The information is of a typical nature only and for details of the actual connections, tap voltages, sequence of operations, etc., used in a particular application, refer to the transformer nameplate.

1. Assume a starting position with both tap selectors on the same tap. In this configuration load current is evenly divided between both sets of contactors and tap selectors.

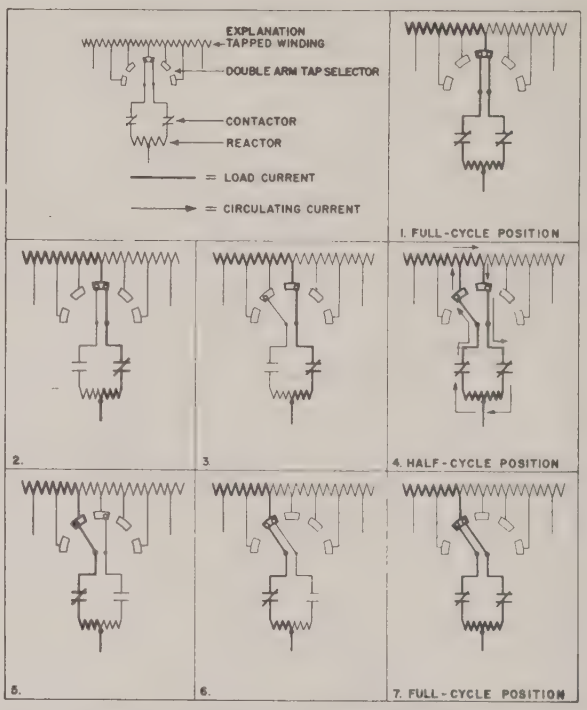


Fig. 6. Schematic diagram of tap changing sequence

2. As a change of taps begins, one contactor opens, diverting the load through the other half of the circuit.

3. The open-circuited tap selector is then free to move to the next tap position without interrupting current.

4. The change of taps is completed when the open contactor is reclosed, requiring approximately 1½ seconds for the entire sequence of operations. In this configuration, a section of the transformer winding is bridged by the tap selectors and, therefore, a reactor has been placed in the circuit to limit the flow of circulating current. By designing the winding and reactor to carry the circulating current, this bridging (or "half-cycle") position can be used as an intermediate operating position and, in effect, doubles the number of taps or steps.

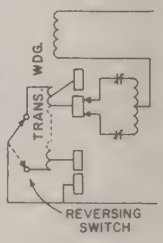
5. If the next change of taps is in the same direction, or in the event the bridging position is not used as an operating position, the opposite contactor will open.

6. Its tap selector then moves to the same tap.

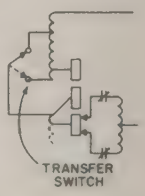
7. The contactor recloses, returning the mechanism to the "full-cycle" position. When the half-cycle position is omitted as an operating position, approximately three seconds are required to move from one full-cycle position to the next.

In addition to doubling the number of steps by means of the half-cycle position, a two-position reversing (or transfer) switch may also be included to double the number of steps again.

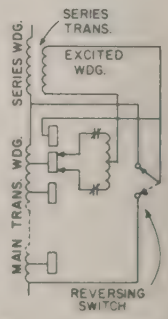
The switch can be used to *reverse* the polarity of the voltage taken from the tapped section, permitting the tapped section to be used twice — one time adding to and the other time subtracting from the voltage of the main winding, or—



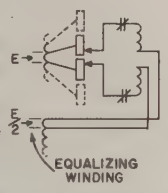
It can be used to *transfer* another section of the main winding into or out of the circuit, also permitting the tapped section to be used twice —once by itself and once with additional turns in series with it.



The addition of a series transformer permits the use of the tap selector switch in circuits where the voltage stresses or current to be interrupted would otherwise exceed the capability of the switch. Its series winding is placed in series with the load and voltage from the tapped section is impressed upon its excited winding. A reversing



switch changes the polarity of the voltage applied to the excited winding, making it possible to add to or subtract from the voltage in the main transformer winding, thus regulating the output. With the tap changer on the middle or neutral position, zero voltage is impressed on the excited winding and the output voltage is neither raised or lowered.



An equalizer winding is sometimes used to reduce the voltage across the arcing contacts of the contactor and to redistribute the circulating current in such a manner as to cause each contactor to share equally in its interruption. This type of circuit can thus be used to advantage in those applications where contact life becomes a limiting design factor.

OFF-POSITION OPERATION

CAUTION—In case of an emergency situation such as failure of the power supply, controls, motor, etc., it is possible for the tap changing mechanism to stop with one of its contactors in an open position (steps 2, 3, 5, or 6, Fig. 6) with the result that all of the load current then flows through one-half of the tap changer circuit. The design of the transformer is such as to permit this type of off-position operation for approximately 12 hours under full load. Beyond this time, either the mechanism must be returned to a normal operating condition or the load current must be reduced to one-half of the maximum nameplate rating in order to avoid possible internal damage to the transformer.

Contacts on auxiliary relay *84Y* can be wired into the user's alarm system to warn of this condition as explained under "Operation, Motor Drive" and as shown on the LTC Control Diagram.

MAINTENANCE

PERIODIC INSPECTION

Check the condition and dielectric strength of the oil in the tap-selector compartment yearly and replace if necessary. Maintain the oil level as indicated by the oil gage. The weatherproof breathers on the oil compartment should be cleaned at intervals to assure proper venting of the gases produced by switch arcing. Make an occasional examination of the self-adjusting oil seal used where the vertical drive shaft enters the bottom of the tap-selector and contactor compartment.

CAUTION—If it becomes necessary to work on any of the circuits associated with the line-drop-compensator current transformer, *be sure to short circuit its secondary before removing the burden.* The secondary circuit of an energized current transformer should never be opened, as dangerously high voltages may develop! These voltages can not only break down insulation and destroy the current transformer, but present a serious hazard to personnel.

Arcing Contacts

The arcing contacts will gradually wear out over a period of time as a result of interrupting current during each tap change. It is recommended, therefore, that these contacts and the entire switch mechanism be inspected after the first two years of service or 25,000 operations, whichever occurs first. The frequency of inspection thereafter should be based on the observed rate of contact wear and any other pertinent factors such as subsequent changes in load conditions, the importance of continuity of service, previous experience, etc., but at no greater than 5 year intervals. Do not dress or file the arcing contacts as this will merely remove useful metal and shorten their life.

The tips of the arcing contacts are approximately 9/16-inch thick when new and should be replaced when this thickness is reduced to ¼-inch measured at the center. To replace the contacts, it is only necessary to remove the worn tips and bolt the new ones in their place. Since the contactor is permanently adjusted at the factory, no adjustment is necessary when new contacts are installed. Replacement tips can be ordered by Catalog Number 8380576, P21 through the nearest Apparatus Sales Office of the General Electric Company. Four arcing tips are required for each phase (two stationary and two movable) or a total of 12 for a three-phase mechanism.

Each time the tap selector and contactor compartment is opened for an inspection or replacement of the arcing contacts, all surfaces of the panels, bushings, shafts, and other insulating parts should be thoroughly cleaned to remove the carbonized oil and metallic particles deposited on them as a result of contactor arcing. Clean by washing with clean, dry transformer oil applied with dry, lint-free cloths; then flush out the interior of the compartment and refill with filtered or new oil.

LUBRICATING

The drive motor is equipped with ball bearings which should be thoroughly cleaned and repacked with a good grade of ball bearing grease every five years. Grease the universal joints on the drive shaft by means of the fittings provided and keep the mechanism gears and controller drum cams lightly greased. Apply a few drops of light motor oil to each shaft bearing annually or as required.

DYNAMIC BRAKING ADJUSTMENTS

The cams on the controller drum and their respective switches should be examined occasionally to see that they are secure. If the drive does not stop exactly on position, the timing of the dynamic braking can be adjusted by slightly shifting the appropriate cam or cams. Refer to "Operation, Motor Drive" and to the Control Diagram. To determine when the mechanism is centered on position, observe the ON-POSITION indicator. The middle cam should be centered on the controller drum when the mechanism is centered on position.

Limit Switches

Operation of the limit switches at the maximum raise and lower positions should be adjusted to coincide with the operation of the controller drum switches. When the LTC mechanism reaches either of its maximum positions, the respective limit switch should open simultaneously with the corresponding controller switch to prevent any further movement in the same direction. To adjust a limit switch, loosen the mounting screw in the roller end of the snap-action switch. Then move the switch so as to advance or retard engagement of the roller with the actuating lever on the position indicator shaft.

MAINTENANCE OF RELAYS

To insure reliable and positive operation of the relays in the control circuit, wipe the sealing surfaces of the magnet frame and armature occasionally with a cloth moistened with a non-volatile cleaning fluid. The surfaces of the silver contacts should be kept clean, but require no further attention until the silver is almost gone. Filing or otherwise dressing the contacts results only in loss of silver and reduces normal contact life.

COUPLING DISASSEMBLY

If it becomes necessary to disconnect any shaft or the coupling connections between the motor drive and the tap selector and contactor, care must be taken to see that all parts are reassembled properly. It is recommended that the mechanism be set on the middle position (see nameplate) and that all parts be match-marked before disassembly. Note the position of the tap-selector movable contacts and the position of the reversing or transfer switch, if one is used. All main and arcing contacts should be fully closed.

The motor drive can be uncoupled

from the tap-selector and contactor by removing four bolts from the flange at the lower end of the oil seal shaft. The universal coupling can then be removed from the motor drive by loosening the set screw which secures it to the motor drive shaft.

CHECK AFTER REASSEMBLY

The first test after any reassembly of the load-tap-changer equipment is to operate the mechanism to each limiting position by means of the handwheel as outlined under "Handwheel Operation." Then set the mechanism on one of the intermediate positions and operate to each limit electrically by means of the manual-control switch. Attempt to operate beyond the end positions and make sure the electric limit switches function properly.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
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GENERAL ELECTRIC

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Load/Vac® Tap Changer

TYPE LRT-200

CONTENTS

INTRODUCTION
- General 1

DESCRIPTION
- Tap Selector 3
- By-Pass Switch 3
- Vacuum Interrupter Assembly 4
- Auxiliary Controls 4
- Control Compartment 5

INSTALLATION
- Inspection 6
- Testing 6
- Connections 7

OPERATION
- Handcrank 7
- Motor Drive 7
- Protective System 8
- Fault Alarm 8
- Tap Changing Sequence 8
- Off-Position Operation 10

MAINTENANCE
- General 11
- Vacuum Interrupter 11

INTRODUCTION

The Type LRT-200 load-tap-changing mechanism utilizes vacuum interrupters to break the current when changing tap positions. Since all arcing takes place within a vacuum chamber, oil contamination is eliminated and the arcing contact life is prolonged.

Control of the motor drive equipment may be either manual or automatic/manual, depending on the requirements of the installation, and can be located at the transformer and/or on a remote panel. When equipped with automatic controls a relatively constant voltage can be maintained automatically at some predetermined load center as the transformer input voltage fluctuates and as load conditions vary.

In the following text, numbers in parentheses refer to items in the various figures and symbols in italics refer to components shown in Fig. 14 and on the LTC Control Diagram. Note that the diagram shown in Fig. 14 is of a typical nature only and for complete details of any particular installation, the user is referred to the Control Diagram furnished with the transformer.

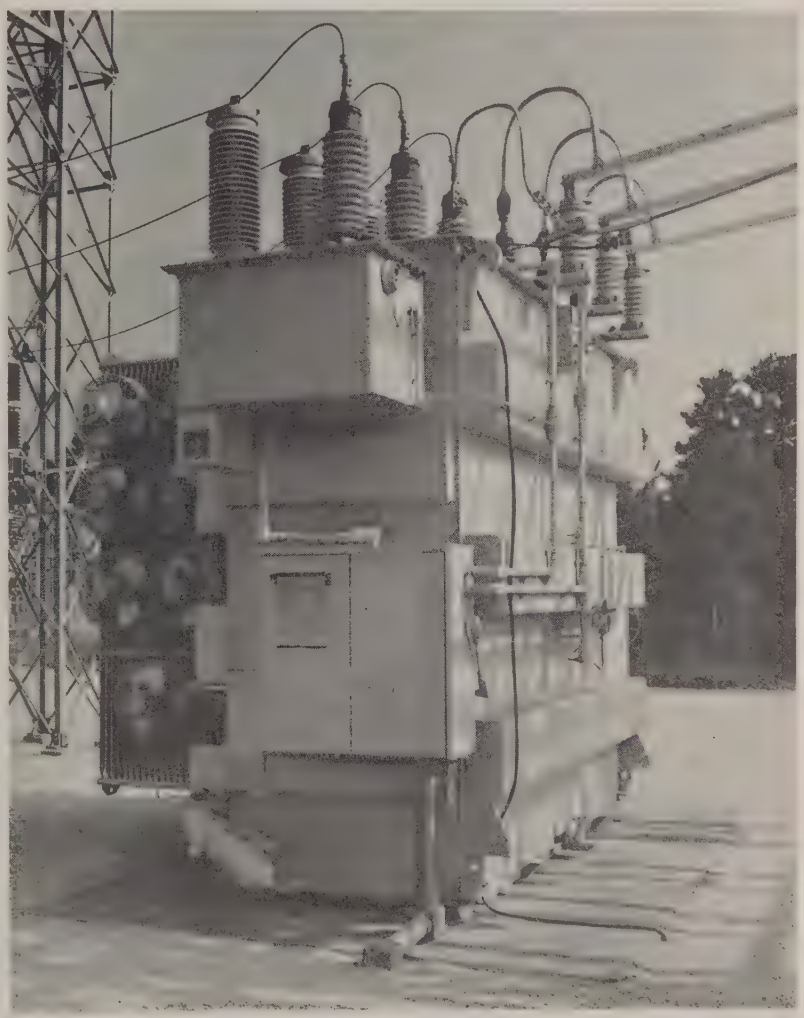


Fig. 1. Load-tap-changing equipment, type LRT-200

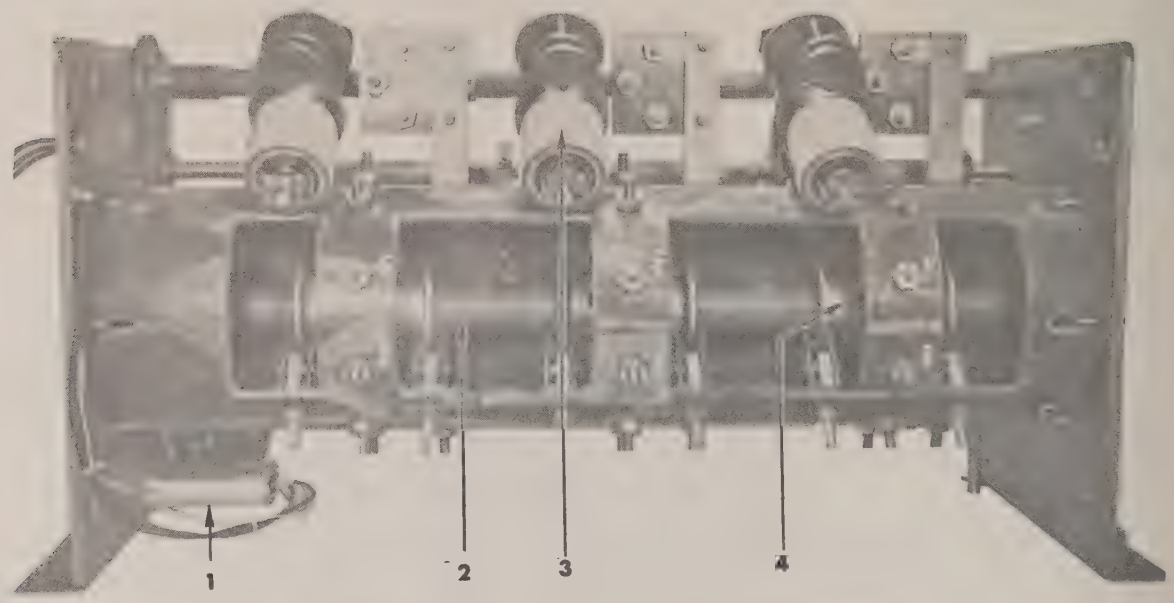
The equipment covered by these instructions should be installed, operated and serviced only by competent technicians familiar with good safety practices, and these instructions are written for such personnel and are not intended as a substitute for adequate training and experience in safe procedures for this type of equipment.

DESCRIPTION

The LTC equipment is assembled in three separate compartments mounted on the end of the transformer tank as shown in Fig. 1. The upper compartment is oil filled and contains the tap

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC



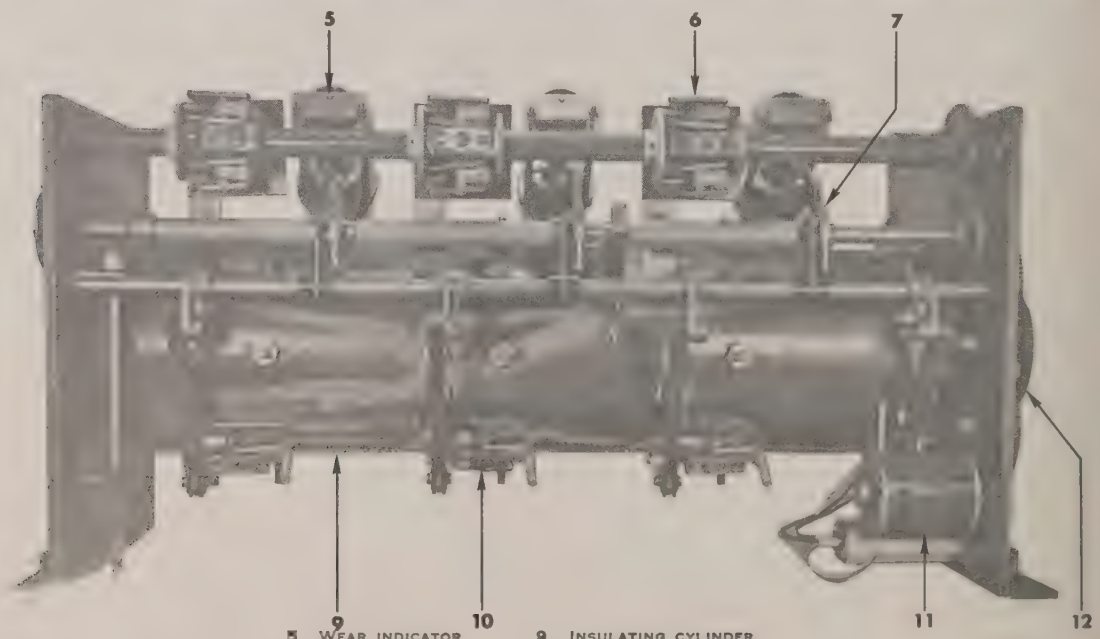
1. MOTOR CAPACITOR
2. CONCENTRIC DRIVE SHAFTS
3. VACUUM INTERRUPTER
4. TAP-SELECTOR SWITCH

Fig. 2. Front view of switch mechanism

selectors, reversing switches, by-pass switches, vacuum interrupters, motor, gears, a portion of the protective circuit, etc. This compartment is sealed to protect the mechanism and its insulating oil from exposure to the atmosphere.

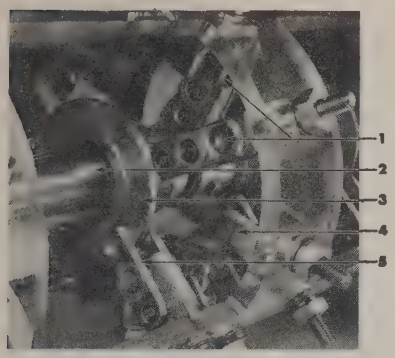
Directly below the oil compartment and attached to it is a small air-filled auxiliary control compartment with a viewing window for observation of the position indicator and containing the limit and cam-operated control switches. The hand-crank drive shaft is also located in this compartment and space has been provided for selsyns and/or other types of remote position indicating devices, as required.

The lower air-filled compartment is mounted at a convenient height above ground level and contains the balance of the automatic LTC control equipment. Provisions are included for various optional control features such as



5. WEAR INDICATOR
6. BY-PASS SWITCH
7. CONTROL CAM
8. CONTROL SHAFT
9. INSULATING CYLINDER
10. REVERSING SWITCH
11. MOTOR
12. REDUCTION GEARS

Fig. 3. Rear view of switch mechanism



1. MOVABLE CONTACTS
2. CONCENTRIC DRIVE SHAFTS
3. MOVABLE CONTACT SLIP RING
4. STATIONARY CONTACT
5. COLLECTOR FINGER

Fig. 4. Tap selector switch

paralleling CT's, lockout relays, voltage reduction controls, etc., plus certain transformer auxiliaries such as a fault pressure relay seal-in circuit, cooling equipment controls, current transformer terminal boards, etc.

TAP SELECTOR

The tap selector (Figs. 2 and 3) consists of three dial-type switches mounted inside a common insulating cylinder (9). Each switch (Fig. 4) has two movable contacts (1) and nine stationary contacts (4). The stationary contacts are arranged in a circle inside the cylinder and are connected to taps in the transformer windings. Each contact has two shelves, one for each of the two movable contacts.

The movable contacts are mounted on two concentric drive shafts (2) and are insulated from one another. Connections are made to these contacts through collector fingers (5) sliding on slip rings (3). One movable contact in each phase is attached to the outer shaft and the others are attached to the inner shaft through slots in the outer shaft. These slots are designed to allow sufficient travel for the inner and outer shafts to rotate the movable contacts independently of one another, making contact with either the same or adjacent stationary contacts as required.

Fig. 6. Reversing switch

A Geneva gear is mounted at the end of each drive shaft and these two gears (1, Fig. 5) are actuated by pins (2, Fig. 5) on a double Geneva gear driver. The arrangement is such that the two shafts and their contacts are locked in position except during tap changes at which time they are rotated in an alternating sequence by the double driver. With the two arms on the same stationary contact, a one-half revolution of the Geneva gear driver causes one arm to move to the next adjacent contact, and on completion of the revolution the second arm is moved to this same contact.

Reversing Switch

Each of the three dial-type tap-selector switches is provided with a separate single-pole, double-throw switch. This switch is used to reverse the polarity of the tapped portion of the transformer winding and thus doubles the number of available tap positions. Mounted near the bottom of the tap-selector cylinder (Fig. 6), its stationary contacts are located inside the cylinder and the remainder of the assembly is bolted on the outside.

The switch is actuated by a boss on one of the Geneva gears acting through a Geneva sector, lever arms, and connecting rods. It remains locked in one position during all operations of the tap selector until the ninth tap is reached. At this point it flips over and is then locked in the opposite position while the tap selector continues on its second revolution.

Positive Stop

In addition to electrical limit switches, the mechanism is provided with a mechanical stop. The stop consists of a lug (3, Fig. 5) on each of the two Geneva gears which comes in contact with the reversing switch actuator when the mechanism reaches its maximum position in either direction. Engagement is made just slightly beyond the point at which the electrical limit switches should stop the mechanism, thus mechanically blocking any further movement beyond the final end positions.

BY-PASS SWITCH

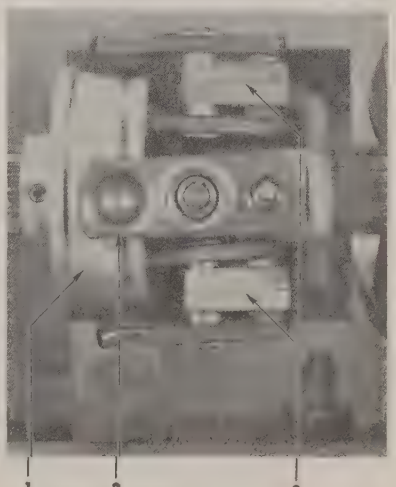
A by-pass switch is used in each phase to shunt current flow around the vacuum interrupter except when taps are being changed. The switch (Fig. 7.) is a circular device consisting of two stationary contact assemblies (3) mounted 180 degrees apart and a semicircular rotating contact (1) which spans an arc of 200 degrees. The moving contact has chamfered leading edges and can be rotated in either direction. Two pairs of collector fingers (2) provide continuous contact throughout each revolution.

1. GENEVA GEARS
2. GENEVA GEAR DRIVER PINS
3. POSITIVE STOP LUG

Fig. 5. Geneva gear assembly

At the beginning of a tap change the connection at one of the stationary contacts is broken causing the current in that half of the circuit to be diverted through the vacuum interrupter. While the interrupter and tap-selector function to change taps, the movable contact continues to rotate and near the end of the cycle it reconnects with the open stationary contact to complete the change. The movable contact thus rotates 180 degrees in each cycle, causing one stationary contact to be opened during one tap change and the other contact to be opened during the next change.

Movements of the tap selectors, by-pass switches, reversing switches, and vacuum interrupters are coordinated in a fixed sequence, causing all contact



1. ROTARY CONTACT
2. COLLECTOR FINGER FOR ROTARY CONTACT
3. STATIONARY CONTACT ASSEMBLIES

Fig. 7. By-pass switch in closed position.

Fig. 8. Dual-slope control cam

arcing to take place within the interrupters. For a detailed description of this series of operations, refer to the section entitled "Tap Changing Sequence."

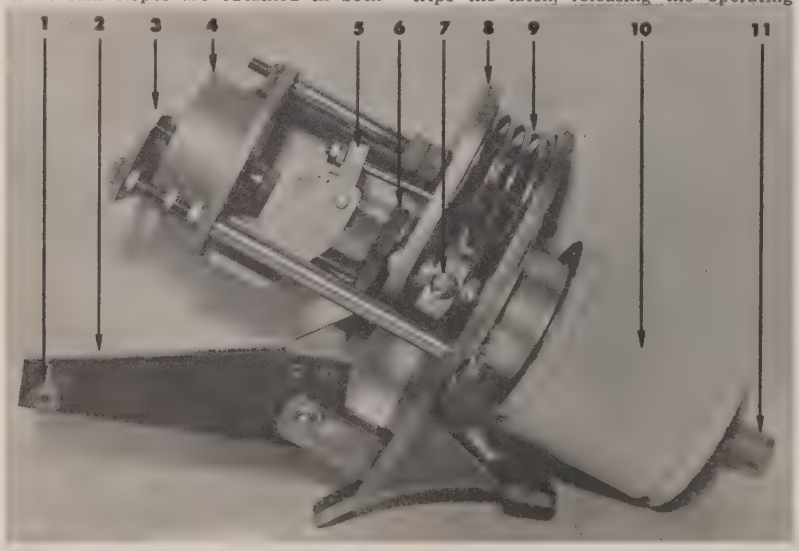
VACUUM INTERRUPTER ASSEMBLY

A special dual-slope cam assembly (Fig. 8) controls the movement of the vacuum interrupter mechanism, providing a steep slope for opening and a moderate slope for closing. The two different cam slopes are obtained in both directions of rotation by means of an auxiliary cam, roller, and spring assembly which controls the position of the two outer segments of the cam; i.e., the steep slope portion.

At the appropriate time during each tap change, the control cam allows the two-piece actuator arm (2 and 8, Fig. 9) to drop abruptly. Spring (9) accelerates this movement of the arm through a short distance of free travel, increasing its momentum prior to striking drive nut (6). This impact followed by a continuing movement in the same direction produces a very rapid opening of the interrupter contacts.

As the moving contact of the interrupter reaches its maximum open position, latch (5) engages an extension of the operating rod (10, Fig. 11) to hold the contacts open temporarily. Inside the vacuum interrupter a metallic vapor arc is produced by the separation of its two contacts. This arc is extinguished during the first current zero owing to the high-speed opening of the contacts and the vapors then disperse and condense on shield (7), thus retaining the high dielectric strength of the vacuum.

When the tap selector has completed its sequence, the moderate slope of the control cam begins to raise the actuator arm and recompress the actuator spring. As the force which opened the contacts is removed, the pressure differential caused by the vacuum within the interrupter acts on the operating rod through bellows (1) to exert a closing force against the latch. Just before the control arm reaches the top of the cam it trips the latch, releasing the operating



1 CAM FOLLER
2 ACTU[illegible]TOR AR[illegible]ER END)
3 WEAR IND[illegible]
4 DASHPOT
5 LATCH
6. DRIVE NUT
7. MOVABLE CONTACT TERMINAL
8. ACTUATOR ARM (UPPER END)
9. ACTUATOR SPRING
10. VACUUM INTERRUPTER
11. STATIONARY CONTACT TERMINAL

Fig. 9. Vacuum interrupter assembly (in open position)

Fig. 10. Wear indicator

rod and initiating a high-speed reclosing of the interrupted contacts, the rate of which is controlled by a dashpot (4, Fig. 9).

Wear Indicator

During each tap change a minute quantity of contact metal is vaporized, resulting in eventual erosion of the contact tips. Since the contacts are not visible, an external wear indicator has been provided above the dashpot on each vacuum interrupter assembly as shown in Fig. 10. An extension of the operating rod protrudes through a hole in the indicator plate and the amount of this protrusion is gradually reduced over the life of the interrupter. Thus when the top of the rod becomes flush with the indicator plate (with the interrupter closed) the contacts are worn out and the interrupter must be replaced.

AUXILIARY CONTROLS

The control shaft (8, Fig. 3) extends down through a self-adjusting seal at the bottom of the oil compartment and into the auxiliary control compartment. This compartment is shown in Fig. 12 with its sheet metal housing removed.

Control Switches and Dynamic Breaking

The sequence of operations required to make a tap change is controlled by cams (5) mounted on control shaft (6). Rotation of the shaft causes the cams to operate contacts of the three sequencing switches *33S* (7). These contacts in turn control the operation of a number of relays and timers to insure completion of the tap changing cycle.

The switching sequence also serves to stop the mechanism exactly on position at the end of each tap change through the use of a dynamic braking circuit. This method of stopping involves the application of a momentary

d-c current across the motor windings at the proper time as explained more fully under "Operation, Motor Drive."

Position Indication

The position indicator (2) is driven by a worm gear on the control shaft. The gear ratio is such as to cause the indicating pointer to move through 320 degrees for the full range of tap changes. Numbers on the dial correspond to tap positions shown on the transformer nameplate and drag fingers show the extremes in operating positions since last reset. The fingers are held in position by a spring and ratchet assembly and can be reset only by means of a solenoid which is energized through a switch on the control panel in the lower control compartment.

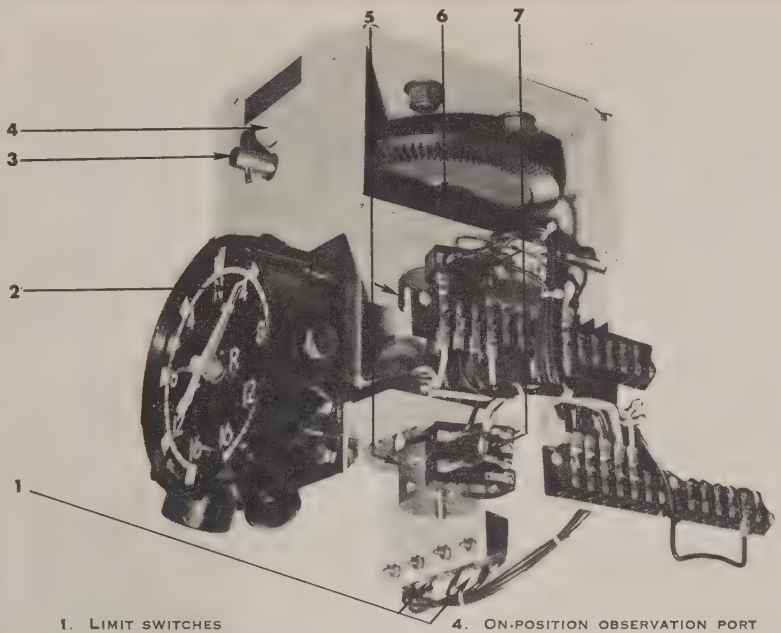
An observation port (4) just above the position indicator provides a visual means of determining whether or not the tap selector and interrupter assembly has stopped on position. Paint marks on the two gears visible through the hole should align themselves with one another at the conclusion of each tap change if the mechanism is functioning properly.

Limit Switches

Snap-action limit switches (1) are mounted behind the position indicator dial and their contacts are wired into the motor relay circuit. A trip lever on the position indicator shaft opens switch *(LS/L)* at the maximum lower position, or switch *(LS/R)* at the maximum raise position, to prevent electrical operation of the mechanism beyond either of the end positions.

CONTROL COMPARTMENT

Items mounted in this compartment, Fig. 13, include an operating panel with control power circuit breaker *8M*, position indicator drag finger reset switch *RS*, operation counter *OC*, raise/lower switch *CST*, auto/manual switch *43T*, remote/local switch *43TRL* (when required); the vacuum interrupter protective system; and the automatic static control equipment (as described in separate instructions). When required, certain other auxiliary transformer devices may also be located in this compartment.

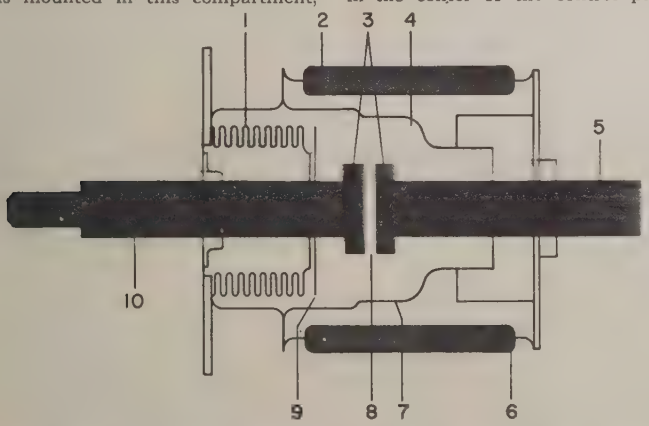


1. Limit switches
2. Position indicator
3. Handcrank coupling
4. On-position observation port
5. Cams
6. Control shaft
7. Sequencing switches

Fig. 12. Auxiliary controls with housing removed

Operation Counter

An operation counter *OC* is mounted in the center of the control panel and is electrically operated through contacts *2-3* of sequencing switch *33S*. Periodic recordings of the counter readings are recommended as a means of determining when to make an inspection of the vacuum interrupter wear indicators. See "Maintenance."



1. Flexible metallic bellows assembly
2. Insulating vacuum envelope
3. Arcing contacts
4. Vacuum chamber
5. Stationary electrical terminal
6. Metal-to-insulation vacuum seal
7. Metal vapor condensing shield
8. Electric arcing region
9. Bellows shield
10. Operating rod (movable terminal)

Fig. 11. Cutaway view of POWER/VAC® vacuum interrupter

Protective System

A protective system has been provided to guard against the possibility of developing an arc across the tap selector in the event that an interrupter should fail to open properly during a tap change. The system utilizes a current transformer in series with each vacuum interrupter (see Fig. 15) and the outputs of these three transformers *CT1P*, *CT2P* and *CT3P* are paralleled as shown in Fig. 14. Switch *S3P* on the mechanism shorts these secondaries while the vacuum interrupters are closed. This switch is cam operated in a sequence which causes it to open just after the vacuum interrupters have opened and to close just before they reclose. Therefore, an output will be obtained from the current transformer circuit only if an interrupter fails to function properly; i.e., only if it continues to carry current at a time when no current should be flowing.

The current transformer output is applied to the gate circuit of silicon controlled rectifier *SCR1P* through a voltage limiting network consisting of rectifiers *CR2P*, *CR3P*, *CR4P*, *CR5P*, and transformer *T2P*. Whenever a signal appears, *SCR1P* is triggered into conduction and will then *continue* to conduct until manually reset by means of switch *S1P*. Conduction through *SCR1P* energizes control

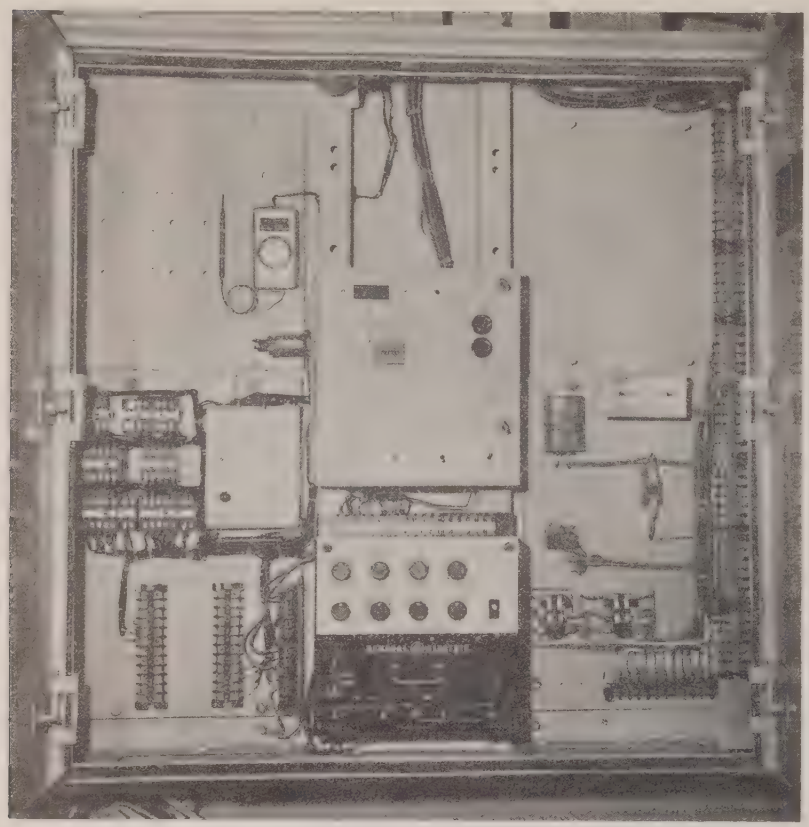


Fig. 13. Control compartment

relay *68*. Relay *68* energizes red fault light *L1P*, initiates a control sequence which stops the motor and returns the mechanism to its last operating position and also opens the control circuits to prevent initiation of any further tap changes. These operations are explained more fully under "Operation, Protective System." Relay *68* is a mechanically latching relay so that the fault indications will not be lost if control power is temporarily lost.

Test switch *S2P* is provided for checking the protective system at installation and occasionally throughout the life of the transformer. Closing this switch introduces a current into the system through resistor *R4P* which is equivalent to that produced by a CT when an interrupter fails to open. The routine for testing is outlined under "Installation."

CAUTION — It should be noted that the protective system is operational only when changing taps under MOTOR control. It DOES NOT provide protection when changing taps by means of the HANDCRANK. Therefore, do not use the handcrank to change taps while the transformer is energized.

INSTALLATION

The load-tap-changing equipment is shipped in place and is to be prepared for service by observing the following installation guide. Do not operate the equipment while a vacuum is applied to either the LTC housing or the main transformer tank.

CAUTION — Note that insulating materials in the oil compartment can absorb moisture during prolonged exposure to the atmosphere. Periods exceeding 60 hours should, therefore, be avoided since a drying cycle may then be required.

INSPECTION

Drain the oil from the tap-selector compartment and make the following inspection.

1. Check for loose or damaged parts.

2. Operate the tap selector with the handcrank and check for binding. See "Handcrank Operation."

3. With the mechanism on an operating position, refer to Fig. 9 and measure the gap between drive nut (6) and upper actuator arm (8) on each interrupter. This gap should be 0.125 ± 0.010 inches. If not, refer to the adjustment procedure outlined under "Interrupter Replacement."

4. Operate through all positions electrically by means of raise/lower switch *CST* and check to see that the limit switches, position indicator, and operation counter function properly.

5. Make sure the mechanism stops on position by checking to see that the paint marks on the two gears above the position indicator are aligned with one another.

6. If the mechanism stops off position or if the limit switches permit *any* movement beyond the maximum positions, refer to the adjustment procedures outlined under "Maintenance."

TESTING PROTECTIVE SYSTEM

Make a check of the vacuum interrupter protective system by holding switch *S2P* in the TEST position and attempting to change taps in the raise direction by means of control switch *CST*. If the protective system is working properly, this will create the effect of an interrupter failure as soon as switch *S3P* opens. The mechanism should remain on position and the drive motor should run only momentarily in the raise direction and then reverse itself. At this point the red FAULT light should also come on, indicating that an interrupter failure has occured and that the controls have been locked out. Check the integrity of this lockout by attempting to operate the mechanism again in both directions using *CST*. No further movement of any kind should take place.

After making the preceding test in the raise direction, press reset switch *S1P* and repeat the same test in the lower direction.

CHECK FOR INTERRUPTER LEAKS

The interrupters are designed to maintain their vacuum integrity throughout their operating life. However, before placing the transformer in service each interrupter should be checked for leaks.

Major leaks as a result of shipping damage, or smaller leaks over an extended period such as during storage, can cause a total loss of vacuum and can be detected as follows.

1. Operate the mechanism manually while carefully observing movement of the wear indicator and all components of the actuator assembly.

2. The wear indicator should travel a distance of approximately 0.1-inch between the open and closed positions. If it does not, and the actuator assembly is working properly, indications are that the interrupter has lost its vacuum and must be replaced.

3. Complete loss of vacuum can be confirmed by making a continuity test as follows. Turn the handcrank until the interrupters open. Connect the leads from a low-voltage continuity tester

(suitable for touching without injury) across the contacts of the interrupter and operate the closing mechanism by hand, i.e., close the interrupter by manually compressing the actuator spring. If the interrupter has lost the major portion of its vacuum, its contacts will not close and, of course, must be replaced.

If preferred, continuity can be checked with the mechanism on an operating position and the interrupters closed by the actuator assemblies. In this case it will be necessary to disconnect the leads from the moving contacts as outlined in the following paragraphs on "Hi-Pot Test."

Minor leaks can substantially reduce the ability of an interrupter to break an electrical arc without affecting its mechanical operation. Since the preceding inspection will not detect problems of this nature, a hi-pot test is also to be made on each interrupter.

HI-POT TEST

Before refilling the compartment, perform a hi-pot test on each vacuum interrupter to make sure it has not lost vacuum during shipment, storage or installation of the transformer. This same test should also be made any time thereafter that faulty operation is suspected such as when the FAULT light comes on. See "Operation."

1. Open control power circuit breaker *8M*.

2. Use the handcrank to run the mechanism until the vacuum interrupters open (until the control cams allow all of the actuator arms to drop).

3. Disconnect the cable lead from the movable contact (top end) at the point where it is bolted to the bus bar.

4. Separate the cable from the bar by at least two inches and connect the "hot" test lead to this cable.

5. Connect the "ground" test lead to the stationary contact, either at the bottom end of the interrupter or at the point where its cable lead is attached to the bus bar (after it passes through the CT).

6. Apply a 10kV a-c (or 14kV d-c) hi-pot test voltage across the interrupter contacts for a period of one minute. Any breakdown indicates loss of a suitable vacuum and requires replacement of the interrupter.

7. Disconnect test leads and reconnect the cables. To avoid strain on the interrupter bellows, dress the cable from the movable contact in such a way that the hole in its crimp connector remains aligned with the hole in the bus bar of its own accord before replacing the bolt.

8. Use the handcrank to continue running the mechanism to the next tap position and check to see that all interrupters reclose properly.

OIL FILLING

Check dielectric strength of the oil and fill the compartment to the 25C level as indicated on the liquid level gage. The manhole should be left open during filling to serve as a vent. The compartment is designed to be sealed for normal operation. After oil filling and sealing, it should be pressurized to 2 psi with *dry* nitrogen gas through the pressure test valve. Thereafter, the pressure-vacuum bleeder will serve to maintain the operating pressure within safe limits.

If there is any reason to suspect that moisture has entered the compartment, it should be removed before filling. Remove any free water first by wiping with dry rags. Any remaining surface moisture can then be removed by drawing a vacuum of 2 millimeters absolute pressure and holding for a minimum of 4 hours. If it is necessary to draw a vacuum, remove the pressure-vacuum bleeder and replace it with a pipe plug.

CONNECTIONS

Refer to the transformer Connection Diagram for accessory wiring in the control compartment and to the LTC Control Diagram for wiring and elementary diagrams of the load-tap-changer control circuits. A removable drill-plate is provided in the bottom of the compartment for making conduit connections.

When provided with automatic controls, note that the 120 volt potential supply must be taken from the circuit to be regulated. For proper, line-drop compensation, the potential supply and the current supply must be in phase on the basis of unity power-factor load current. When a reclosing relay is provided for the main circuit breaker feeding the transformer, refer to the notations on the Control Diagram for special connections to prevent initiation of a tap change under fault conditions.

OPERATION

HANDCRANK

The load-tap-changing mechanism can be operated manually by means of a handcrank for inspection and maintenance purposes. A handcrank coupling is provided above the position indicator (3, Fig. 12) and the crank itself is stored inside the air compartment to the left of the control panel. To operate the mechanism by hand, de-energize the control circuits by opening control power circuit breaker *8M* and use the handcrank to turn the coupling. Approximately 3 turns are required to make a change of one tap. There will be a noticeable increase in the torque required to turn the crank at one point during each tap change owing to the force required to recompress the actuator springs.

The position indicator will show the tap position and also the direction in which taps are being changed. Watch the indicator and the on-position paint marks on the beveled-gear drive assembly to make sure the mechanism is stopped at an operating position. The mechanical stop becomes effective on the end positions to prevent further hand operation beyond limiting positions if such operation is attempted.

Note that removing the handcrank from its mounting bracket opens interlock switch *84I* to de-energize the motor drive circuit. After changing taps manually, the handcrank must be replaced on its bracket before the motor can be operated again. After replacing the crank, reclose breaker *8M* to place the mechanism back under motor control.

WARNING—The protective system is inoperative when the taps are being changed by hand! Therefore do not attempt to change taps with the handcrank while the transformer is energized as serious damage to the transformer and/or personal injury may result!

MOTOR DRIVE

Manual operation of the motor drive can be obtained by placing switch *43T* on MANUAL and momentarily placing *CST* in either the RAISE or LOWER position. (Hold in contact long enough for the seal-in circuit to establish itself.) Automatic control is obtained by placing *43T* on AUTO. Once a tap change has been initiated, control of the mechanism is taken over by the control cams and their related switches, *33S*. The operating sequence of these switches is illustrated in the typical motor-drive control diagram of Fig. 14.

Assuming that a change of taps has been called for in the raise disection, the motor drive equipment will function as follows (temporarily disregarding the function of protective relays *68, 68X/R* and *68X/L):*

1. Motor raise relay *84R* is energized through normally closed contacts *7-8* of relay *84L* and limit switch *LS/R*.

2. Once relay *84R* has been energized, the following occurs:

   a. Contacts *1-2* close to seal-in relay *84R* through contacts *22-23* of switch *33S* (which are closed by the bottom cam as soon as the motor begins to run).

   b. Contacts *3-4* close to energize motor *84*.

   c. Contacts *7-8* open to lock out the corresponding lower circuit.

   d. Contacts *9-10* open to prevent dynamic braking power from being applied to the motor while it is being energized through relay *84R*.

3. As the mechanism moves off position, contacts *1-2* (top cam) of *33S* open to de-energize auxiliary relay *84X*.

a. Its contacts *1-2* then open to disconnect the automatic controls and reclose with a time delay following completion of the tap change. This delay allows time for the automatic controls to determine whether or not the voltage requirements have been satisfied before initiating any additional changes.

b. Contacts *3-4* close to prepare for the dynamic braking operation to follow.

c. Contacts *7-8* close to by-pass the seal-in contacts for motor lower relay *84L*. (No time delay, either opening or closing.) This action serves to protect the mechanism from remaining off position (see "Off-Position Operation") in the event of temporary loss of control power.

If the power supply should fail, relay *84R* would drop out, losing its seal-in and preventing any further movement in the raise direction. However, at the same time it would also reclose its contacts *7-8*, thereby completing the lower circuit and allowing the mechanism to return to the next lower operating position upon return of power. At that point the control would revert to normal and the mechanism would then be free to move again as required.

4. Contacts *1-2* of *33S* also de-energize auxiliary relay *84Y*. Contacts *3-4* and *5-6* of this relay can be connected by the user to provide remote on- and off-position indication as shown on the Control Diagram.

5. Contacts *2-3* of *33S* close and open during each tap change to provide a pulse for operation counter *OC*.

6. When the mechanism approaches the next operating position, *33S* contacts *1-2* reclose to energize relay *84X* and:

a. Initiate the time delay for the automatic controls.

b. Initiate the time delay for the dynamic braking circuit.

c. Defeat the off-position emergency run-back circuit.

7. At the same time, *33S* contacts *22-23* reopen to drop out relay *84R*, thus removing a-c power from the motor. Contacts *3-4* of *84X* maintain a circuit through rectifier *CR* and resistor *RES* to pass d-c (half-wave rectified a-c) through both motor windings, effecting dynamic braking. After approximately one second, contacts *3-4* open to remove the d-c power from the motor.

8. The sequence of operations for changing taps in the lower direction is essentially the same as those outlined for raising except that the change is initiated through relay *84L*.

PROTECTIVE SYSTEM

If, for any reason, a vacuum interrupter fails to open properly at the beginning of a tap change, relay *68* will be picked up and sealed in as previously outlined under "Description." Assuming a change has started in the raise direction, relay *68* then causes the following actions to take place:

1. Contacts *13-19* and *14-20* will open to disconnect the manual and automatic controls, preventing any further changes from being initiated in either direction.

2. Contacts *17-20* close to energize auxiliary relay *68X/R* through the *84R* seal-in circuit consisting of *33S* contacts *22-23* and *84R* contacts *1-2* plus contacts *11-12* of auxiliary relay *68X/L*.

3. When *68X/R* picks up, the following simultaneous actions occur:

a. Contacts *9-10* open to de-energize relay *84R* which in turn stops the motor from running any further in the raise direction.

b. Contacts *3-4* close to seal in *68X/R* through lower contacts *12-13* of sequence switch *33S* (middle cam).

c. Contacts *1-2* close to apply power to lower relay *84L*, causing the motor to run in the opposite direction and returning the mechanism to its starting position.

d. Contacts *7-8* close to by-pass the lower limit switch contacts *11-12* of *LS/L*. This insures completion of the circuit to energize relay *84L* in the event that the mechanism happens to have started raising from the maximum lower position at which time the lower limit switch contacts may be open.

e. Contacts *11-12* open to provide an interlock with relay *68X/L*, preventing it from being energized at the same time as *68X/R* (through contacts *16-19* of *68* which will be closed at that time).

4. When the mechanism has returned to its starting position, contacts *12-13* of *33S* open to de-energize both *84L* and *68X/R* and the system then returns to normal except for relay *68* which remains sealed in through *SCR1P*.

5. Contacts *13-19* and *14-20* of *68* will remain open and continue to prevent any attempt to change taps by either the manual or automatic controls until such time as reset switch *S1P* is closed.

FAULT ALARM

When the FAULT light *L1P* comes on this is an indication that a loss of vacuum has occurred in an interrupter and that the protective system has operated to return the motor drive to its starting position and block any further attempts to change taps. The transformer can operate satisfactorily in this condition indefinitely but it will no longer have the ability to change taps.

CAUTION — Do not attempt to change taps by means of the handcrank under these conditions as the protective system will not prevent such changes and serious damage to the transformer and/or personal injury may result!

A confirmation that the interrupter has failed should then be made by resetting the system with *S1P* and attempting to change taps one more time under motor control using switch *CST*. If the mechanism successfully completes this change, the lockout was probably the result of some unrelated voltage transient and can be ignored.

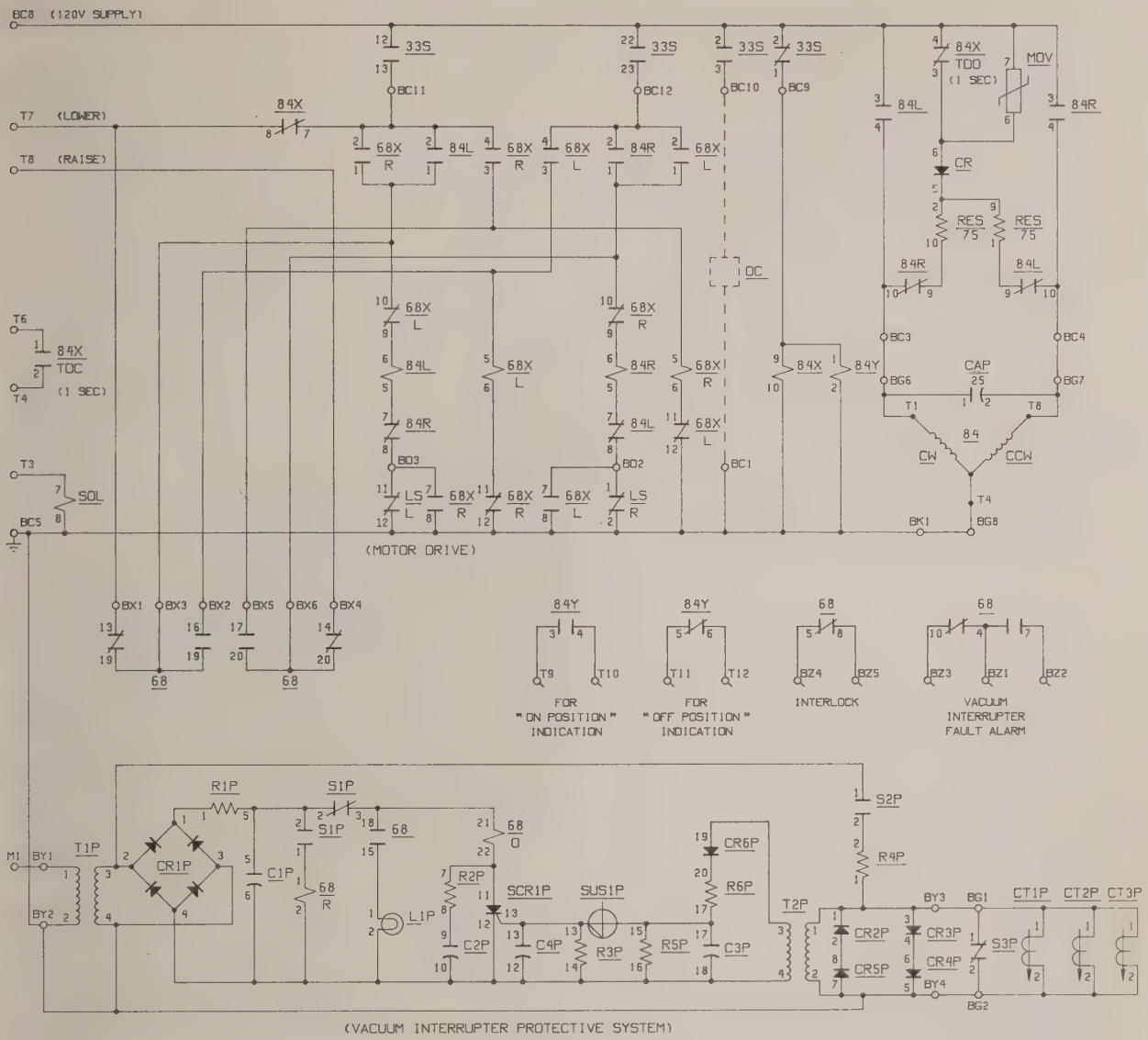
If the fault light comes on again, leave the controls locked out and take the transformer out of service for further inspection as soon as convenient. Make a visual examination of the mechanism in accordance with the procedures outlined under "Installation." In particular, look for such things as loose, worn, or broken parts; binding; misalignment; etc. Also check for proper movement of the wear indicators and actuator assemblies while changing taps manually. If no problems are found during this examination, the lockout was most likely caused by a slight loss of vacuum in one of the interrupters, resulting in its failure to extinguish the arc properly. Hi-pot testing should then be performed to locate the defective component.

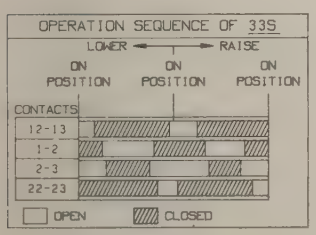
TAP CHANGING SEQUENCE

The sequence of operations and the methods of connecting the tap selectors, by-pass switches and vacuum interrupters are described in the following paragraphs and the corresponding steps are illustrated in Fig. 15. The information is of a typical nature only and for details of the actual connections, tap voltages, sequence of operations, etc., used in a particular application, refer to the transformer nameplate.

1. Assume a starting position with both of the tap selector's movable contacts on the same stationary contact. In this configuration load current is evenly divided between both sets of contacts and the two by-pass switches. This is referred to as the "full-cycle" position.

2. As a change of taps begins, one





LEGEND

33S	SEQUENCING SWITCH FOR 84, MECHANICALLY OPERATED	L1P	RED FAULT INDICATING LIGHT
68	CONTROL RELAY, LATCHING - O = OPERATE, R = RESET	LS	LIMIT SWITCH
68X	AUXILIARY RELAY FOR 68	MOV	VARISTOR
84	OPERATING MOTOR	R	RAISE
84L, 84R	MOTOR REVERSING RELAYS	R1P-R6P	RESISTOR
84X	AUXILIARY RELAY FOR MOTOR CONTROL	S1P	RESET SWITCH
84Y	AUXILIARY RELAY FOR MECHANISM POSITION INDICATION	S2P	TEST SWITCH
		S3P	CURRENT TRANSFORMER SHORTING SWITCH
C1P-C4P	CAPACITOR	SCR1P	SILICON CONTROLLED RECTIFIER
CAP	CAPACITOR	RES	RESISTOR
CR	DC BRAKING RECTIFIER	SOL	SOLENOID (DRAG-HAND RESET)
CR1P-CR6P	RECTIFIER	T1P, T2P	TRANSFORMER
CT1P-CT3P	CURRENT TRANSFORMER	TDC	TIME DELAY CLOSING
CW	CLOCKWISE	TDO	TIME DELAY OPENING
CCW	COUNTERCLOCKWISE	OC	OPERATION COUNTER
L	LOWER	VIPS	VACUUM INTERRUPTER PROTECTIVE SYSTEM
		SUS1P	SILICON UNILATERAL SWITCH

Fig. 14. Typical motor drive control diagram

by-pass switch opens, diverting its half of the load through the vacuum interrupter.

3. The interrupter then opens, breaking one-half of the load current and causing the entire load to be carried through the remaining half of the circuit.

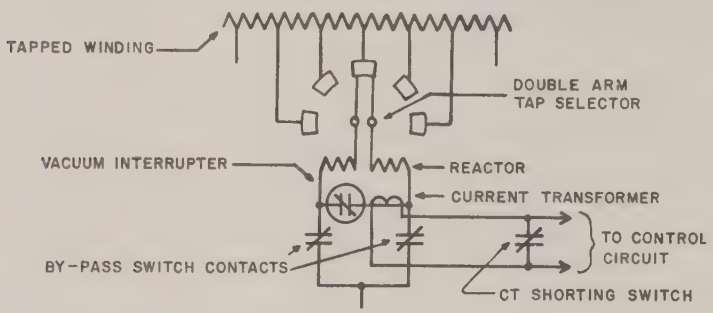
4. The open-circuited contact of the tap selector is then free to move to the next tap position without interrupting current.

5. The vacuum interrupter recloses to redivide the load.

6. The change of taps is completed when the open by-pass switch is reclosed, requiring approximately 2.2 seconds for the entire sequence of operations. In this configuration, a section of the transformer winding is bridged by the tap selectors and, therefore, a reactor has been placed in the circuit to limit the flow of circulating current. By designing the winding and reactor to carry the circulating current, this bridging (or "half-cycle") position can be used as an intermediate operating position and, in effect, doubles the number of taps or steps.

7. If the next change of taps is in the same direction, or in the event the bridging position is not used as an operating position, the opposite by-pass switch will open.

8. The interrupter opens again and a sequence of operations continues in the same manner as before until both movable contacts of the tap selector again come to rest on the same stationary contact returning the mechanism to the "full-cycle" position as shown in Step 11. When the half-cycle position is omitted as an operating position, approximately 4.4 seconds are required to move from one full-cycle position to the next.



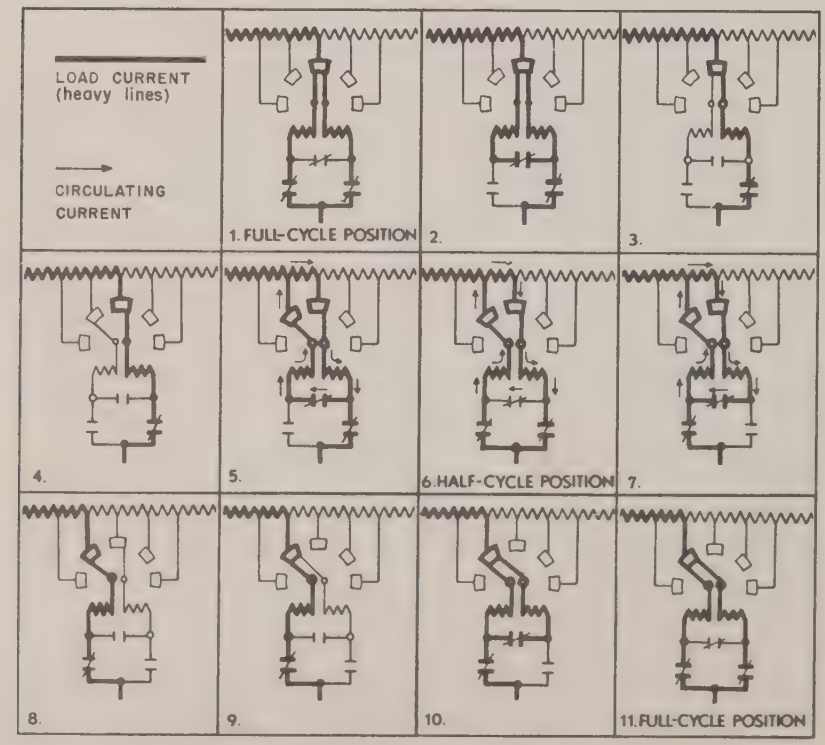
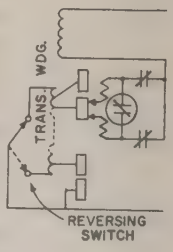
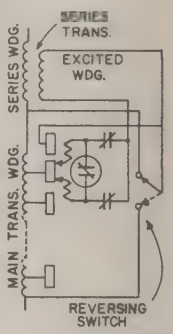


Fig. 15. Tap changing sequence

In addition to doubling the number of steps by means of the half-cycle position, a two-position reversing switch is also included to double the number of steps again. The switch is used to reverse the polarity of the voltage taken from the tapped section, permitting the tapped section to be used twice—one time adding to and the other time substracting from the voltage of the main winding.



The addition of a series transformer permits the use of the tap selector switch in circuits where the voltage stresses or current to be interrupted would otherwise exceed the capability of the switch. Its series winding is placed in series with the load and voltage from the tapped section is impressed upon its excited winding. A reversing switch changes the polarity of the voltage applied to the excited winding, making it possible to add to or substract from the voltage in the main transformer winding, thus regulating the output. With the tap changer on the middle or neutral position, zero voltage is impressed on the excited winding and the output voltage is neither raised nor lowered.



OFF-POSITION OPERATION

In the event of an emergency situation such as failure of the power supply, controls, motor, etc., it is possible for the mechanism to stop with one of its by-pass switches open as in Step 2 (Fig. 15) or with a by-pass switch and an interrupter open as in Step 3. Although operation in the Step 2 condition is undesirable, it should not cause any damage to the transformer. However, in the Step 3 condition all of the load current must pass through half of the reactor circuit.

CAUTION — The design of the transformer is such as to permit off-position operation with an interrupter open for approximately 12 hours under full load. Beyond this time, either the mechanism must be returned to a normal operating condition or the load current must be reduced to one-half of the maximum nameplate rating in order to avoid possible internal damage to the transformer.

Contacts on auxiliary relay *84Y* can be wired into the user's alarm system to warn of an off-position condition as explained under "Operation, Motor

Drive" and as shown on the LTC Control Diagram.

MAINTENANCE

GENERAL

The following items should be inspected at yearly intervals or as dictated by the user's maintenance experience.

1. Check the condition and dielectric strength of the oil in the tap-selector compartment and replace if necessary. Maintain the minimum oil level as indicated by the liquid level gage.

2. Examine the self-adjusting oil seal at the point where the control shaft (6, Fig. 12) enters the bottom of the oil compartment.

3. Check operation of the protective system as outlined under "Testing Protective System." If the FAULT light is on, review the paragraphs under "Fault Alarm."

4. Check to see that the gear-teeth paint marks are properly aligned when viewed through the on-position observation port (4, Fig. 12). If the drive does not stop exactly on position, the control cams and their respective switches should be examined to see that they are secure. The timing of the dynamic braking can be adjusted by slightly shifting the appropriate cam or cams. Refer to "Operation, Motor Drive" and to the Control Diagram.

5. Keep the mechanism gears and control cams lightly greased.

CONTROL CIRCUITS

CAUTION — If it becomes necessary to work on any of the circuits associated with the line-drop-compensator current transformer, *be sure to short circuit its secondary before removing the burden.* The secondary circuit of an energized current transformer should never be opened, as dangerously high voltages may develop! These voltages can not only break down insulation and destroy the current transformer but present a serious hazard to personnel.

Relay Maintenance

Relay contact surfaces should be kept clean but require no further attention until the silver is almost gone. Filing or otherwise dressing the contacts results only in loss of silver and reduces normal contact life.

VACUUM INTERRUPTER

The arcing contacts within the interrupter will gradually wear out over a period of time as a result of interrupting current during each tap change. It is recommended, therefore, that the wear indicators (Fig. 10) and the entire switch mechanism be inspected after the first two years of service or 25,000 operations, whichever occurs first. The frequency of inspection thereafter should be based on the observed rate of wear and any other pertinent factors such as subsequent changes in load conditions, the importance of continuity of service, previous experience, etc., but at no greater than 10-year intervals.

When the interrupters are new and in the closed position, the wear indicator pins protrude 0.070-inches above the surrounding surface of the indicators. When this protrusion has been reduced to zero, the interrupters are no longer suitable for service and must be replaced. As an aid in determining the percentage of remaining life, the amount of protrusion can be roughly measured with a special "go or no-go" gage provided with each transformer for this purpose.

The gage consists of a square brass bar with one end machined off to a different depth on each of the four sides. These four steps are graduated to represent the amount of pin protrusion corresponding to 100%, 75%, 50% and 25% of remaining contact life. To use the gage, place the machined end of it squarely against the surface of the wear indicator adjacent to the pin and attempt to slide the various graduations over the pin. The remaining life will be in the range of percentages between the step that will just go over the pin and the next smaller step that will not.

Interrupter Replacement

New interrupters will be furnished as an assembly, complete with actuator, springs, latch, dashpot, wear indicators, etc. as shown in Fig 9. Assemblies can be ordered by Catalog No. 229A2079 G1 through the nearest apparatus Sales Office of the General Electric Company. One assembly is required for each phase, or a total of three for the entire mechanism. All of the necessary adjusting and tightening has been done at the factory and no further changes should be made in any of these settings since improper techniques can damage the interrupter and/or prevent the assembly from functioning properly.

To replace a vacuum interrupter assembly disconnect the two cable leads and remove the three mounting bolts and the associated retainer plate from inside the mounting cylinder. When installing the new assembly, a gap of 0.125 ± 0.010 inches is to be established between the drive nut (6) and upper actuator arm (8). This is to be measured with the three mounting bolts tight and the cam roller (1) on top of its cam, i.e., with the interrupter in the closed position. An approximation of the required gap can be obtained with the mounting bolts partially tightened but loose enough to permit a gentle tapping motion to drive the assembly back and forth within the tolerance of the mounting holes.

Before replacing the cable leads a hipot test should be conducted as outlined under "Installation." Be sure to observe the comments on positioning of the movable contact lead before reconnecting.

CLEANING

Each time the switch compartment is opened for inspection or maintenance, the oil should be drained and all surfaces of the mechanism and its tank should be thoroughly cleaned. Clean by washing with clean, dry transformer oil applied with dry lint-free cloths; then flush out the interior of the compartment and refill with filtered or new oil.

LIMIT SWITCHES

Operation of the limit switches at the maximum raise and lower positions should be adjusted to coincide with the operation of the cam operated control switches. When the mechanism reaches either of its maximum positions, the respective limit switch should open simultaneously with the corresponding control switch to prevent *any* further movement in the same direction. To adjust one of the snap-action limit switches, loosen the mounting screw at the roller end and move the switch so as to advance or retard engagement of the roller with the actuating lever on the position indicator shaft.

COUPLING DISASSEMBLY

If it becomes necessary to disconnect the position indicator or control shaft or to remove the LTC mechanism from the oil compartment, care must be taken to see that the parts are reassembled correctly. It is recommended, therefore, that the mechanism be set on the middle tap position (normally the neutral position — see transformer nameplate) before disassembly and again before reassembly. If in doubt about the position of the tap selector switch, its middle position can be established by placing both of the movable contacts on the stationary contact labeled "M" on the cylinder wall.

CHECK AFTER REASSEMBLY

After any reassembly of the load-tap-changing equipment, the appropriate test routines outlined under "Installation" should be repeated.

MEDIUM TRANSFORMER DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

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Secondary Unit Substation Transformers

LIQUID-FILLED

CONTENTS

	PAGE
Receiving	1
Installation	1
Vault Ventilation	2
Gaskets	2
Accessories	3
Bushings	6
Insulating Liquid	7
Filtering and Drying	9
Maintenance	9

RECEIVING, HANDLING, AND STORING

RECEIVING

Secondary Unit Substation transformers are normally shipped completely assembled, liquid-filled and ready to install. Immediately upon receipt of the equipment, examine the packages and parts for any damage which may have occurred during shipment. If injury or rough handling is evident, file a damage claim with the transportation company and notify the nearest Sales Office of the General Electric Company.

Tighten any parts which may have worked loose, such as nuts and leads and check the materials against the shipping list for possible shortages.

HANDLING

Lugs are provided for lifting the complete transformer, and where necessary, additional nuts and eyes are supplied for lifting the various parts. Lift the transformer by means of the main lifting lugs, using cables long enough to obtain cable pull angles not over 30 degrees from vertical. When lifting the transformer, the cover should be securely fastened in place to prevent buckling the tank walls.

Jacking space is provided in the base of the transformer. Do not attempt to move the unit by placing jacks under drain valves, cooling tubes or other attachments. Junction boxes, when provided, can be removed to facilitate moving the transformer.

STORING

Before placing a transformer in storage, make sure the insulating liquid is at its proper level, add *dry* nitrogen in the gas space until the pressure reaches 3 psi and then seal the unit. Before placing a transformer in service after a period of storage, relieve the internal gas paressure by venting to the atmosphere. See paragraph on "Venting".

Transformers stored for use as spares should be maintained in the same condition as those in service. Make periodic inspections of the liquid level, its dielectric strength, and when furnished, fans, alarms, and control circuits. Also check the pressure gage to make sure the transformer seal is being maintained and inspect junction boxes and other compartments for evidence of moisture condensation.

INSTALLATION

This transformer is to be installed in such a manner and location as to minimize the hazards to all those who have access to it.

The equipment covered by these instructions should be installed operated, and serviced only by competent technicians familiar with good safety prac-

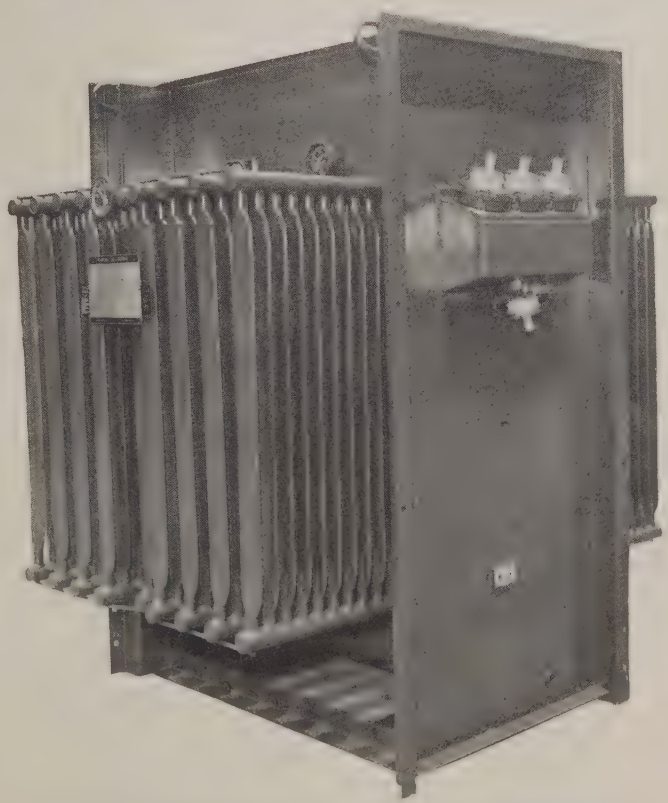


Fig. 1. Secondary unit substation transformer

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

GENERAL ELECTRIC

tices, and these instructions are written for such personnel and are not intended as a substitute for adequate training and experience in safe procedures for this type of equipment.

The only foundation necessary is a level floor strong enough to support the weight of the transformer. The transformer should be located at least six inches and preferably a foot or more away from walls and other obstructions which might prevent free circulation of air around the unit. Provisions have been made for moving valves and gages from the high-voltage to the low-voltage front and vice versa in the event that it becomes necessary to reverse the position of the transformer. Refer to the Outline drawing. Transformer finishes and components are designed for normal life in a non-corrosive atmosphere. Atmospheres which include corrosive agents may require additional protective measures.

If the transformer is to be opened outdoors on a damp or stormy day, take precautions to prevent entrance of moisture. CAUTION — Before removing a handhole cover, shipping plate, or other device, vent the transformer to atmospheric pressure.

Drilled flanges are provided on both the high- and low-voltage ends of the transformer for making connections to switchgear or terminal compartments. Terminal compartments, when provided, can be removed to facilitate installation of the transformer. To disassemble a compartment, remove the bolts around the edge of the front panel and pull it away at the bottom until the top slides out from under the cover. The cover and side panels can then be removed as required. Protective covers on bushings should not be removed until the unit is ready for connection in order to prevent damage to the bushings.

Before placing the transformer in service, check the level and dielectric strength of the insulating liquid in all compartments as explained under "Sampling" and "Testing".

At higher altitudes, decreased air density reduces transformer cooling efficiency and lowers bushing arc-over voltages. Lower atmospheric pressures may require venting of the transformer before placing in service in order to equalize internal and external pressures. If the transformer is to be installed at an elevation above 3300 feet, consult the nearest Sales Office of the General Electric Company relative to the transformer's suitability for operation at the higher altitude.

CONNECTIONS

The necessary hardware for making interconnections between a transformer and its co-ordinated switchgear is supplied with the switchgear. Bus bar joints should be properly aligned before bolting to prevent undue strain on the bushings. When making line connections, long sections of unsupported conductor should be avoided and leads should be flexible enough to allow for expansion and contraction. Make no connections except those authorized by the transformer nameplate.

Transformers having internal terminal boards are normally shipped connected for the highest rated voltage. When shipped otherwise, a tag fastened to the nameplate will indicate the connections that have been made. Before applying voltage to a transformer, see that all connections are tight and that the windings are connected for the desired voltage.

Ground the transformer permanently and effectively by means of the ground pad located at the bottom of the tank. Unit substation transformers can usually be connected to the common substation bus. A reliable, low-resistance ground is essential for adquate protection. A poor ground may be worse than none at all as it gives a sense of false security to those working around the equipment and may result in serious personal injury or damage to the transformer.

When a transformer is designed for use on a system having a solidly grounded neutral, be sure that the neutral lead is permanently and solidly grounded.

PIPE FITTINGS

When assembling pipe fittings, clean the threads thoroughly to remove all insulating liquid, grease, old compound and dirt. Apply GE Compound No. A15A11A or Teflon tape to the threads and screw the mating parts tightly in place.

LEAK TESTS

Inspect the entire transformer for evidence of leaks and make the following pressure test. Introduce dry nitrogen through the pressure test valve (located on the tank wall opposite the pressure-vacuum gage) until the pressure in the transformer reaches 5 psi. Seal the tank at this pressure and make an examination for leaks over a period of 12 hours. Leaks above the liquid level can be located by applying a liquid soap solution to all gasketed joints, pipe fittings, etc.

VENTING

The transformer should be vented to the atmosphere before it is placed in service if it has been pressurized for leak tests or storage, or if the unit has been opened and resealed. Venting should take place with the liquid temperature at 25 C. If it is necessary to vent at other temperatures, re-vent as soon as the unit returns to 25 C. This operation is necessary to prevent excessive operating pressures or vacuums.

VAULT VENTILATION

If the transformer is to be installed in a vault, provide ventilation which is adequate to keep the room temperature from exceeding that of the incoming air by more than 5 C. The number and size of air outlets required will depend on their distance above the transformer, and on the efficiency and load cycle of the apparatus. In general, provide about 20 square feet each of inlet and outlet openings for every 1000 kva of transformer capacity.

Arrange the air inlets and outlets so that they are permanently open. Do not use as ventilators, windows or doors which may be opened and closed by attendants, because of the danger of excessive heating in case they are inadvertently left closed during periods of heavy load or high temperature.

If forced ventilation is used, supply about 5000 cubic feet of air per minute for each 1000 kva of transformer capacity, and conduct the incoming air directly to the transformer so that it will flow up through and around the radiating members of the tank. If this cannot be done and the air is merely moved through the room, provide about 10,000 cubic feet per minute for each 1000 kva.

GASKETS

A number of different types of gaskets are used on secondary unit substation transformers, depending on the application. Gaskets used to maintain the transformer seal have been selected for their ability to resist deterioration by the insulating liquid and to avoid any contamination of the liquid. No substitution should be made for these original gasket materials without the approval of the General Electric Company. Replacement or spare gaskets can be purchased to size through the nearest Sales Office of the General Electric Company. Identify the parts wanted as shown under "Renewal Parts List".

All of the gaskets used to maintain

the transformer seal can be reused many times unless damaged. Before installing a new gasket or replacing an old one, thoroughly clean the gasket surfaces. Although no stickers are required, the compound furnished with the gaskets may be used on all but the "O" rings to hold them in place during assembly. Compress the gasket approximately one-third, or to the stops when provided in either the mating parts or in the gasket itself. Gaskets are compressed to the stops when there is a noticeable increase in the torque required to tighten the bolts. A leak test is recommended following the opening and closing of any gasketed joint affecting the transformer seal.

WEATHERPROOF JOINTS

A length of sponge rubber gasket is furnished with each outdoor unit for the purpose of weatherproofing the joints between the transformer and its associated air-filled compartments. Install this gasket just outside the mounting studs or bolt holes and for the best weather-resistant joint allow the piece across the top to overlap the two side pieces.

To install a sponge rubber gasket, clean the surface on which it is to be mounted and apply a thin coat of the adhesive furnished to both the metal and the gasket. (Do *not* apply adhesive to the edges or outside surface of the gasket.) Allow the adhesive to dry until it is no longer tacky and then press the gasket against the metal with enough pressure to make a good contact.

When a retaining strip is provided the gasket should be assembled with its inner edge in contact with the strip. Tighten the gasket down to this stop or in the absence of a stop, compress it to approximately ½ size.

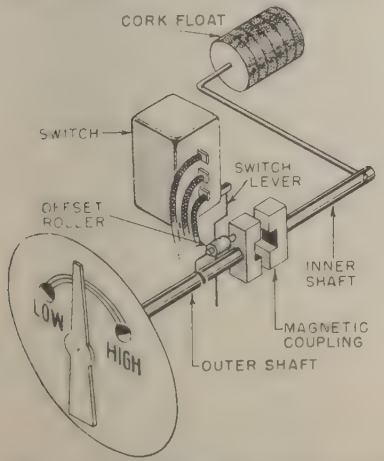


Fig. 2. Schematic view of magnetic liquid-level gage with alarm switch

ACCESSORIES

LIQUID-LEVEL GAGE

A magnetic liquid level gage is used to indicate the level of the insulating liquid in the main transformer tank and in associated compartments. It consists of a float arm and magnet on one side of a liquid-tight partition and a second magnet and indicating pointer on the other side. See Fig. 2. The gage can be removed whenever the liquid is at or below the 25 C level.

Gages which have a snap-action switch can be wired to give an alarm when the liquid level approaches a point too low for safe operation of the transformer. A cam on the indicator shaft will operate the switch when the pointer drops to the "LOW" mark on the dial. As the liquid level rises the pointer indicates the change, but the switch will not clear the alarm circuit until the pointer has advanced from five to ten degrees above the "LOW" mark.

LIQUID TEMPERATURE INDICATOR

The liquid temperature indicator is used to indicate the top liquid temperature of the transformer and those having internal switches can be used to control fans and/or initiate an alarm. The standard type AL thermometer is shown in Fig. 3. When alarm contacts are required a Type ALR thermometer as shown in Fig. 4 will be furnished.

The thermometer is mounted with its temperature sensitive bulb in a well which extends into the transformer's top liquid and is secured with a union nut. The well is liquid-tight thus permitting removal of the thermometer without lowering the liquid level or breaking the transformer seal.

Dial calibration is in degrees centigrade with a yellow or white pointer to indicate top liquid temperature and a red pointer to show the maximum temperature which has been attained since last reset. To reset the maximum reading pointer, remove the magnet and wipe it across the face of the dial.

Type ALR indicators are equipped with two snap-action switches which are operated by cams on the indicating pointer shaft. Switch No. 1 is intended for fan control and Switch No. 2 can be used in an alarm or control circuit. Switch contacts are normally set to operate on rising temperatures as follows: Switch No. 1, 65C; Switch No. 2, 90C. With falling temperatures the switches operate between 5C and 10C below these settings. When Switch No. 1 is used for fan control, a separate "Hand-Auto" switch is included in the control circuit for manual operation.

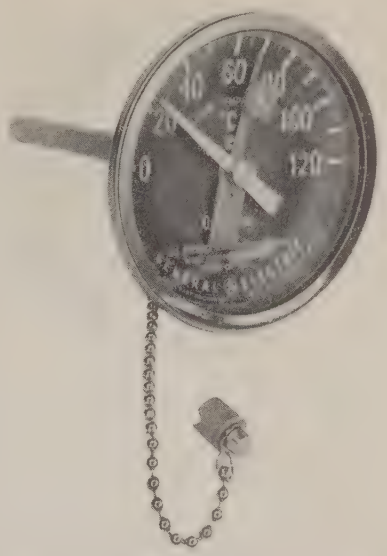


Fig. 3. Type AL liquid temperature indicator

To check operation of the thermometer or the temperature at which the switches operate, remove the unit and place the detector bulb in a container of liquid. Heat the liquid and using an accurate centigrade thermometer, compare readings and check switch operating temperatures. If the unit is not operating satisfactorily consult the nearest Sales Office of the General Electric Company regarding repairs or replacement.

Fig. 4. Type ALR liquid temperature indicator-relay

Fig. 5. Pressure-vacuum gage

PRESSURE-VACUUM GAGE

The pressure-vacuum gage furnished with the transformer (Fig. 5) is of the compound type and is normally calibrated in psi. Gage readings should vary as the transformer temperature changes and should normally indicate a positive pressure. (The instrument should not be expected to read accurately near the zero point.) When the transformer is de-energized or is operating under light or no-load conditions in a low ambient temperature, the gage may indicate a vacuum within the tank. A lack of any change in reading with changes in temperature is an indication of a leak in the transformer seal and should be investigated.

PRESSURE RELIEF DEVICE

The mechanical self-resetting pressure relief device is used on transformers to protect the tank against excessive and dangerous pressures which may build up inside the transformer tank. When a predetermined pressure is exceeded, the force of the pressure build-up lifts the diaphragm and vents the tank. The pressure relief device is normally mounted on top of the transformer either on the main cover or on a manhole cover. It is occasionally used on associated liquid-filled compartments.

Description

The pressure relief device consists of a dome-shaped stainless steel diaphragm held in place by compression springs, suitable gaskets, a protective hood, and a lightweight plastic pin which gives visual indication that the unit has operated. See Fig. 6.

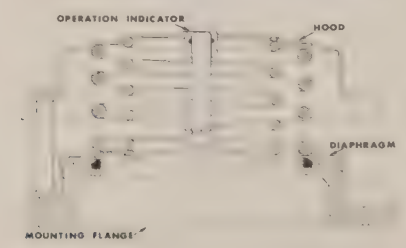


Fig. 6. Pressure-relief device

Operation

When the force of the pressure build-up within the tank against the stainless diaphragm in the pressure relief device exceeds the force of the compression springs, the diaphragm lifts slightly and gas is exhausted through the space between the diaphragm and the lower casting. The tank pressure then spreads over the entire diaphragm area, causing the device to open rapidly and remain open until the pressure within the tank falls well below the tripping pressure. Then the diaphragm reseats and seals the tank to prevent entrance of moisture or foreign material.

As the diaphragm rises during operation it lifts and brings into view a plastic pin located in the center of the cover. This indicates that the relief device has operated. This pin will remain visible until reset manually by being pushed down flush with the top of the pressure relief cover. (See Fig. 7.) The pressure at which the relief is set to operate is determined by the operating pressure of the transformer tank. The tank operating pressure is shown on the transformer nameplate and is also embossed on the relief device. Tanks operating up to 5 psi have reliefs set at approximately 8 psi, and 7.5 psi tanks have their reliefs set at approximately 11.5 psi.

Gas Absorbers and Vent Pipes

If a Pyranol® filled transformer is located in a poorly ventilated indoor area, provisions should be made either to absorb or to carry off any discharged gases. Refer to the National Electric Code for regulations pertaining to the indoor installation of Pyranol® filled transformers.

Gas absorbers are designed for mounting directly on top of the pressure relief. Instructions for installing and filling the absorber are furnished with that device.

A special adapter flange with gasket and reducer, is available upon request for connecting a vent pipe to the relief device. (See Fig. 8). If the vent pipe adapter flange is ordered with the transformer, the bolt circle shown in Fig. 8 is furnished. If the vent pipe adapter is not furnished with the transformer and added as a supply part, studs will have to be added to the cover to give bolt circle shown. Order vent pipe adapter by drawing number 112A4035 G4 through nearest Sales Office of the General Electric Company.

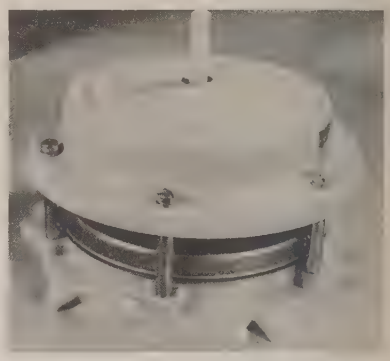


Fig. 7. Pressure-relief device with operation indicator in view

CAUTION

Removal. The pressure within the transformer tank or any separate compartment is acting on the pressure relief device. Bleed off this pressure before attempting to remove the pressure relief device.

Disassembly. Should it be necessary to disassemble the pressure relief device, caution must be exercised when removing the protective hood because the springs are under compression.

Painting. If the pressure relief device is painted in the field, care must be taken that paint is kept away from the space between diaphragm and flange, and away from the indicator bushing.

ELECTRICAL ALARMS

When electrical alarms are furnished with the various devices, the arrangement of contacts and color-coding of the leads will be as shown in Fig. 9 and on the transformer Connection Diagram. Switch No. 1 of the liquid temperature indicator is rated to carry 15

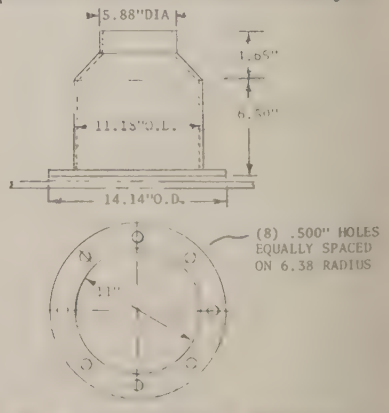


Fig. 8. Vent pipe adapter

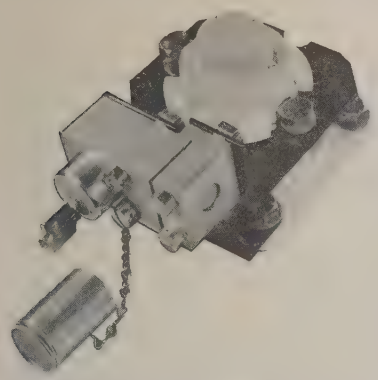


Fig. 12. Tap changer operating mechanism with key interlock

can be done either by means of a special padlock inserted through the head of the oversize cap screw or by means of a captive key-operated plunger-type lock as shown in Fig. 12. The key for this lock is normally held in a similar lock on the primary circuit breaker and can be removed only by opening the breaker and locking it open. This de-energizes the transformer and permits the key to be removed and used to unlock the tap changer.

To place the transformer back in service after the desired tap change has been made, lock the tap changer in position, remove the key, and unlock and reclose the primary circuit breaker.

NOTE: A duplicate key is furnished with the transformer. This key is for emergency use only and should be removed from the operating area to insure the effectiveness of the interlock system.

Removing and Reassembling

If it becomes necessary to disconnect or remove a tap changer drive mechanism it should be placed on position 1 before removal in order to facilitate reassembly. To remove the drive mechanism, unbolt the flange and lift the device out as an assembly. Note that drive mechanisms are not interchangeable! When two or more are removed at the same time, care should be taken to assemble them in the same location from which they were removed.

When replacing, see that the tap changer and the drive mechanism are both on position 1. The tap changer is on position 1 when the wedge bridges tap leads A and B and the index marks on the drive shaft and support structure are in line with one another. To reassemble, place the drive shaft through the opening in the mounting flange and slide the coupling over the tap changer shaft. The slotted end of the coupling should engage a pin in the tap changer shaft without difficulty if both mechanisms are in the proper position.

After reassembling, check to see that the wedge seats itself properly in each position by observing the torque required to turn the drive mechanism in each direction. The mechanism will be at the center of a high torque region when the wedge is properly seated. If the device was correctly reassembled, the position indicator should accurately show the various positions.

Testing

Before placing a transformer in service, test the tap changer to determine that the positions are correct and the steps progress in accordance with the transformer nameplate. To do this, apply a low voltage to one winding (normally the high-voltage) and measure the voltage on the other winding for each tap changer position. *CAUTION — The turns ratio must be taken into consideration when making this test, as voltages endangering the operating personnel may be present.*

BUSHINGS

Porcelain is used as the major insulation in sidewall bushings and upon receipt, an inspection should be made for chips and cracks. If there is evidence of damage or rough handling, file a claim with the transportation company promptly and notify the nearest Sales Office of the General Electric Company. If it becomes necessary to replace a porcelain, the change can be made externally after the liquid level has been lowered below the bushing.

DETACHABLE-CABLE TYPE

To remove the porcelain on a detachable-cable type bushing as shown in Fig. 13, bend locking collar (2) back and remove it along with hex-head nut (1). Remove nuts (5), washers (6) and clamp (7). Porcelain (4) can then be removed and stud (3) will remain attached to the transformer leads from inside the tank. When installing a new porcelain, be sure gasket stop (8) is in position, use new gaskets (9), and torque nuts (5) from 10 to 17 foot-pounds.

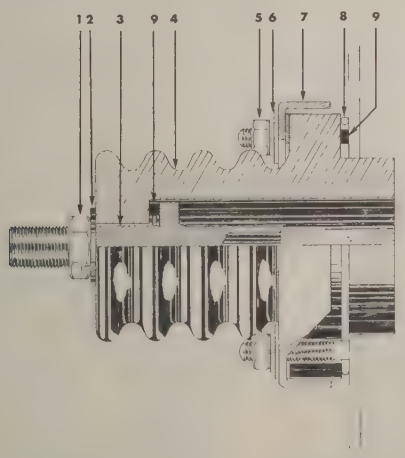


Fig. 13. Detachable - cable type bushing

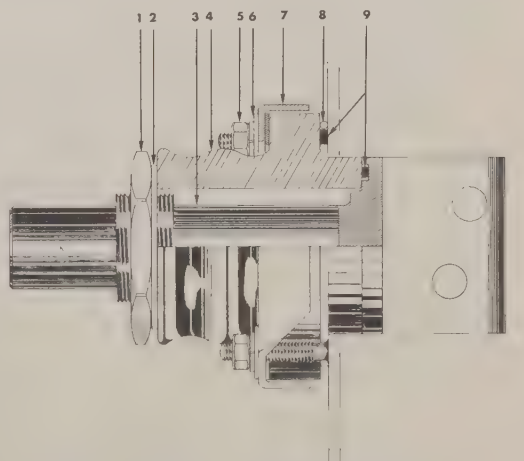
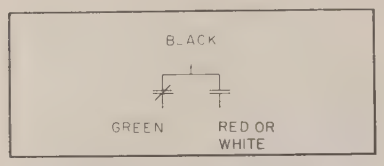
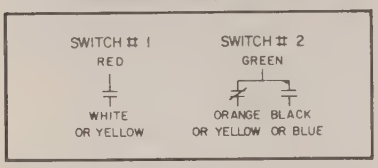


Fig. 14. Stud type bushing



A. LIQUID LEVEL GAGE OR PRESSURE RELIEF DEVICE



B. LIQUID TEMPERATURE INDICATOR

NOTE -- COLOR CODING OF ONE LEAD MAY DIFFER. UNLESS OTHERWISE SPECIFIED BY USER, CONNECTIONS WILL BE MADE TO THE NORMALLY OPEN CONTACTS AND LEADS FROM THE NORMALLY CLOSED CONTACTS WILL BE TAPED UP.

Fig. 9. Switch and cable connections for alarm contacts (when furnished)

amps at 115 or 230 volts a-c. All other snap-action switches are rated as follows:

Circuit	Type of Load	Circuit Volts	Amperes
AC	Inductive and Non-Inductive	115	10
		230	5
DC	Inductive	125	0.05
		250	0.03
	Non-Inductive	125	0.25
		250	0.20
AC or DC	Inductive	125 And 250	Restrict starting inrush currents to values below
			Already Closed Contacts: 30 / Closing Contacts: 15

WEDGE-TYPE TAP CHANGER

The wedge-type tap changer, Fig. 10, provides a means of changing the voltage ratio of a de-energized transformer without breaking the transformer seal. It is shipped in place and is set on the position corresponding to the rated voltage shown on the transformer nameplate unless otherwise requested by the user.

Tap leads from the transformer windings are connected to a circular group of nickel-plated copper rods which are held together between two insulating heads. A wedge in the middle can be moved by a crankshaft to wedge between any two adjacent rods. A spring between the wedge and crankshaft maintains a high-pressure line contact between current carrying components.

When the crankshaft is turned to move the wedge from one operating position to another, pressure is gradually reduced on the spring and the wedge is withdrawn from between rods. A "U"-shaped guide on the opposite side then pivots the wedge around to the next set of rods. As the crankshaft continues to turn, pressure is again applied to the spring and the wedge is forced into position with a wiping action, insuring positive contact.

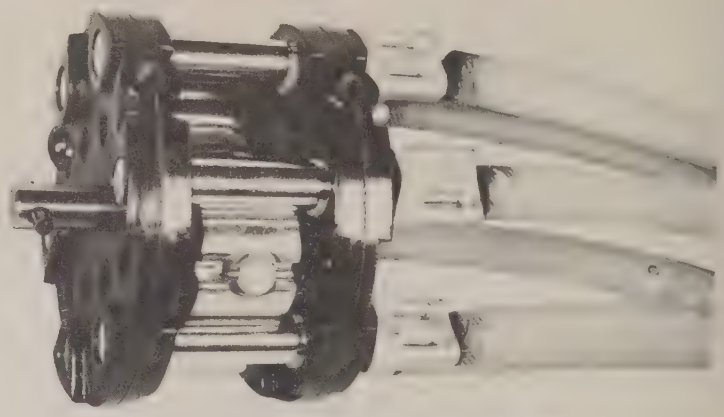


Fig. 10. Wedge-type tap changer

The drive mechanism, Fig. 11, is located on the side or cover of the transformer and is connected through an insulator to the crankshaft of the tap changer. The cap covering the mechanism is gasketed to the mounting flange and an "O"-ring gasket is used between the mounting flange and drive shaft to maintain the transformer seal. One of the screws used to hold the cap in place has an oversize head with a hole in it for padlocking if desired. When requested, provisions can also be included for interlocking with the primary circuit breaker (or high-voltage disconnect switch) as explained under "Interlocks". Position indication is provided by an arrow on the mounting flange and a corresponding number on the cap.

Operation

CAUTION! The tap-changer must not be operated while the transformer is energized! Serious personal injury and/or damage to the transformer may result if this is attempted.

A table on the transformer nameplate gives the voltage and current rating for each tap position. TO CHANGE TAPS REMOVE THE TAP CHANGER CAP and use a wrench to turn the hex-head drive mechanism. The mechanism must be rotated through 5/6 of a turn to make a change of one tap. With the cap removed, the tap position can be observed through a slot in the indicator cams (See Fig. 11). Although the drive mechanism can be turned continuously in either direction placing the wedge in any one of six different positions, only five positions are numbered for use as shown on the transformer nameplate. The unnumbered position is unauthorized and should not be used.

After the desired change has been made, make sure that the cap gasket is in good condition and replace the cap. Note that the slots in the two indicator cams must coincide before the cap can be seated properly. This is to insure that the cap is not replaced until the tap changer is on position and also serves to align an appropriate position number on the cap with the arrow on the mounting flange.

Interlocks

Upon request, the operating mechanism can be mechanically interlocked with the circuit breaker or disconnect switch feeding the transformer. This

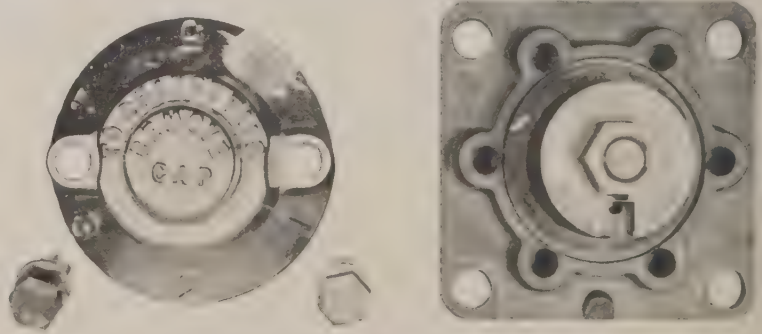


Fig. 11. Tap changer drive mechanism with cap removed

STUD-TYPE

To replace the porcelain on a stud-type bushing as shown in Fig. 14, remove hex-head nut (1) and flat washer (2). Remove nut (5), lock and flat washers (6), and clamp (7). Porcelain (4) can then be removed leaving terminal stud (3) attached to the winding leads. When installing a new porcelain, be sure gasket stop (8) is in position, and torque nuts (5) from 10 to 17 foot-pounds.

INSULATING LIQUID

The insulating liquid must be maintained at the proper level (see nameplate) and for the longest possible service life of the transformer, the dielectric strength of its insulating liquid should be maintained at a high value. It is recommended, therefore, that the liquid be sampled and tested after the first few days of operation, again after six months, and yearly thereafter. Keep accurate records of the tests and filter or replace the liquid as indicated.

The sampling and testing procedures are outlined in subsequent paragraphs. Where suitable equipment and qualified personnel are not available for conducting these tests, the user may wish to avail himself of the following testing service.

TESTING SERVICE

For convenience in sampling and testing, the General Electric Company will, upon receipt of an order through one of its Sales Offices, furnish one-quart sample containers. These will be supplied clean, dry and sealed with a small dessiccant capsule inside to prevent contamination with moisture. This capsule should be examined for a color change from the normal blue and then discarded. If the capsule was either white or pink, the bottle should be dried in an oven for four hours at 110°C. Since reliable tests are dependent on reliable samples, follow the techniques outlined under "Sampling Insulating Liquids".

Return sample containers to the General Electric location designated by the Sales Office. Pack these samples carefully to avoid breakage in transit. Recommendations for continued use or treatment will be furnished, based on the following tests.

1. Dielectric strength
2. Acidity
3. Water content
4. Color
5. Condition

To assist the laboratory in furnishing the most useful recommendations from the results of the tests, supply the following information:

1. Give the serial number and rating of the transformer.

2. State the transformer top oil temperature.

3. State whether or not the sample represents the liquid originally furnished with the transformer and if not, when and why it was replaced.

4. State the date the sample was taken.

5. State why the tests are considered desirable and give any other information that might have a bearing on the condition of the liquid.

HANDLING INSULATING LIQUIDS

NOTE: The following instructions concerning insulating liquids are intended to cover 10 C® and 10 CA* oil-filled transformers. Refer to the transformer nameplate to determine the type of insulating liquid in the transformer. If the insulating liquid is other than 10 C or 10 CA oil refer to the instruction book for that liquid for additional information.

10 C Oil

When handling General Electric 10 C insulating oil, use only metal or oil-proof synthetic rubber hose for oil lines. The sulphur in natural rubber hose will dissolve in the oil and prove harmful to the copper in the windings.

10 CA Oil

General Electric 10 CA oil consists of GE 10 C oil with a minimum of 0.15% by weight of an approved antioxidant such as DBPC (2, 6 di-tertiary butyl para cresol), added to extend its oxidation life. The antioxidant is not normally required since modern sealing techniques exclude atmospheric oxygen. The two oils are interchangeable and can be mixed in any proportion with a corresponding dilution of the antioxidant. 10 CA oil can be handled in the same manner as 10 C oil and with the same equipment.

Instructions on handling the antioxidant itself and the procedure for adding it to 10 C oil are contained in a technical publication, GET-2486. Should it become desirable to add DBPC to reconditioned or new oil in the field, copies of this publication can be obtained from the nearest Sales Office of the General Electric Company.

FILLING TRANSFORMERS

Transformers are normally shipped liquid-filled. If it should become necessary to refill a transformer, make sure all joints are tight and vent the tank to the atmosphere while filling. In order to prevent aeration, it is preferable to fill the transformer through the drain valve with a filter system. Fill to the level indicated on the transformer nameplate in accordance with the prevailing temperature.

If tests on the insulating liquid are satisfactory and no filter system is available, fill the transformer through a cover opening. Strain the liquid through two or more thicknesses of muslin or other closely woven cotton cloth which has been thoroughly washed and dried to remove the sizing. Use at least one set of cloths for each transformer.

SAMPLING INSULATING LIQUIDS

In the sampling and testing of insulating liquids, strict attention should be given to the cleaning and drying of sampling and testing receptacles. Samples should be taken when the insulating liquid is at least as warm as the surrounding air to avoid the possibility of moisture condensation. If the transformer or drum is outdoors, the sample should be taken on a clear day with precautions being taken to guard against contamination by windblown dust, etc. Observe the following procedure to obtain consistent results from samples taken either for field or factory tests.

Sampling From Transformers

1. Impurities which tend to affect the dielectric strength of 10 C oil will generally be found at the bottom of the transformer. Therefore, on oil-filled transformers the sampling valve is located on the main drain valve.

2. A one quart, small neck, brown glass bottle is the preferred sampling container. When subscribing to the testing service previously described, this type of bottle is required. For testing at the site other containers may be used provided they are thoroughly cleaned. If metal containers are used be sure all traces of soldering flux are removed from the seams. Do not use rubber or a composition of rubber for the gaskets or stoppers.

3. To clean the bottles, rinse with a dry, hydrocarbon solvent such as kerosene. Then wash with strong soapsuds, rinse thoroughly with distilled water, and dry in an oven at 105° C to 110° C for at least 8 hours. After

Fig. 15. Typical portable dielectric test set

drying, the bottles must be tightly sealed. Store them in a dry, dust-free cabinet or compartment.

4. Carefully clean the sampling valve or plug and allow enough insulating liquid to run out to remove any moisture or foreign matter which may have collected.

5. Rinse the bottle carefully, at least three times, with small portions of liquid drawn from the sampling valve. Allow the sampling bottle to drain thoroughly between rinses.

6. Draw a sample into the bottle, leaving sufficient air space (approximately one inch) to allow for possible expansion of the liquid. Reseal the transformer and carefully seal the container to prevent exposure to the atmosphere.

7. When making repeated samplings, observe the transformer liquid level and add make-up liquid as required.

Sampling From Drums

1. Drums should remain undisturbed for at least eight hours before being sampled.

2. Glass theives should be cleaned dried and stored in the same manner as outlined for bottles.

3. Take the sample about ⅓" from the bottom observing the precautions previously outlined.

TESTING INSULATING LIQUIDS

Dielectric Strength

A variety of high-voltage dielectric testing equipment may be purchased from the General Electric Company. A typical portable test set (Model No. 9T11Y8454) is shown in Fig. 15 and various console models are also available. Proper testing routines are covered by ASTM Method D877. The following paragraphs give a general outline of the procedure.

1. Set the spacing of the 1.0 inch diameter electrodes at 0.100 inch.

2. Wipe the test cup and electrodes clean with dry, calendered tissue or clean, dry chamois and thoroughly rinse with a dry, hydrocarbon solvent such as kerosene.

3. Fill the test cup with dry, solvent and make a breakdown test under standard conditions of voltage applications (3 kv per second rise). If the cup has a dielectric strength above 25 kv, it is considered suitable for testing purposes. Observe the usual precautions in handling solvents.

4. Immediately after the final rinsing with solvent, rinse the test cup with the sample under investigation, and proceed with the test at once.

5. *The temperature of the sample when tested should be the same as that of the room, which should be between 20 C and 30 C (68 F and 86 F).* Tests made on samples above this temperature can be misleading. Under no circumstances should the test cup be colder than the sample being tested.

6. Agitate the sample gently before each filling to prevent variations in results due to a settling of contaminants. Pour the liquid into the receptacle slowly to avoid the formation of air bubbles and fill to overflowing. If air bubbles are present, gently rock the test cup a few times and wait at least 3 minutes before applying voltage.

7. Fill the cup at least five times, making one test per filling, and average the results.

Since the liquid is a major portion of the insulation system in the transformer, its dielectric strength should be maintained as high as possible. A low breakdown voltage is an indication that impurities such as moisture, conducting dust, lint, or carbonized particles have entered the liquid. Oil testing lower than 26 kv (30 kv when new) should either be filtered to bring it back to its original condition or be replaced, depending on the condition of the liquid and economic considerations.

Other Tests

Although a low dielectric strength indicates the presence of contaminants, a high value is not always a certain indication of their absence. A number of other tests can be performed on an insulating liquid to determine its condition and therefore no one test should be considered conclusive. ASTM Method D117 defines the standard tests and contains cross references to other ASTM Designations for detailed descriptions of each method.

Field Test For Moisture Content

The following field test can be used to detect the presence of excessive amounts of moisture in the insulating liquid:

1. Obtain a sample of the insulating liquid when the transformer is at operating temperature. (Preferably above 40 C.)

2. Starting with the hot sample, rinse a clean, dry test tube with the liquid to be tested, fill half full and stir continuously with a centigrade thermometer while cooling to approximately 20 C. Cool as much as possible in the ambient air and complete the cooling by momentarily dipping the test tube in an ice bath, removing and stirring and then redipping, etc.

3. Observe the sample carefully and note the temperature at which initial cloudiness appears. Wipe the outside of the tube with a clean rag or paper towel to facilitate observation of the slight moisture cloud that may form. Compare to clean insulating liquid at ambient temperature in a similar tube if necessary. Examination for the presence of a cloud should preferably be made against a dark background and not directly into the sunlight.

4. If cloudiness appears at 20 C or above, high to excessive moisture content is indicated.

   A. Inspect the unit for free water.

   B. If free water is not present, a sample should be forwarded to the Laboratory for a quantitative analysis and recommendations on treatment of the unit. See "Testing Service."

5. If cloudiness does not appear until the temperature is below 20 C, an acceptable moisture content range is indicated.

6. This field test for moisture should be regarded as a rough test only and if there is any reason to question the condition of the insulating liquid, a sample should be sent to the Laboratory for an accurate analysis.

FILTERING AND DRYING INSULATING LIQUIDS

If test results indicate that moisture or other contaminants are present, they can usually be removed by passing the liquid through a filter system. Any free water in the transformer should be removed before the filter operation if started. For details of the procedure to be followed refer to instructions GEH-754. Copies of this publication can be obtained from the nearest Sales Office of the General Electric Company.

A transformer contaminated with moisture will not only have moisture suspended in the insulating liquid, but also in the windings and insulation. The most efficient temperature for filtering moisture from the transformer is between 20 C and 40 C, but at this temperature the transfer of moisture from the windings and insulation to the insulating liquid is quite slow. In order to completely dry the transformer, the filtering operation should be followed by a short-circuit heat run.

Drying A Transformer

Recommendations regarding the drying of any particular transformer can be obtained from the nearest Sales Office of the General Electric Company. Requests for this information should include the serial number of the transformer and the voltages and kva available for drying, including any available step-up or step-down transformers, etc. A more detailed explanation of drying procedures can be found in instructions GEI-65070 copies of which can also be obtained through the Sales Office.

The first step in drying a transformer consists of removing any free water and the water in solution as previously explained under "Filtering and Drying Insulating Liquids." The moisture remaining in the windings and insulation can then be driven off by heating the transformer. *Exercise caution when heating the transformer to avoid damaging the insulation.* The maximum winding temperature as determined by resistance measurements should not be allowed to exceed 95 C. CAUTION — Any drying method which involves heating an oil-filled transformer when it is exposed to the atmosphere also creates a serious fire hazard. No smoking or open flames should be permitted near the transformer and suitable fire extinguishers, preferably the carbon dioxide type, should be on hand before beginning the dryout.

Heating the transformer can be accomplished by shorting one winding and applying a suitable voltage on the other. Full-load current can be obtained by applying the impedance volts of the transformer. *Be sure to load the entire winding.* If the transformer is at room temperature at the start of drying, 125 per cent load may be applied until the top liquid temperature reaches 65 C. At this point, the current should be reduced in accordance with the following table:

Max. Allowable Short-Circuit Amps in Percent of Full Load	Maximum Top-Oil Temperature in Degrees C
100	75
85	80
50	85

Since the windings are at a higher temperature than the insulating liquid, the insulation may be damaged if these values are exceeded. Filtration during the heat run will not greatly hasten the drying process, because at these temperatures the filter press loses its ability to remove any appreciable amount of moisture.

The air space in the transformer must be thoroughly ventilated to remove the water vapor given off. This can be done by removing manhole covers, the pressure-relief device, or the entire cover. If drying is done indoors, provide good ventilation to exhaust vapors from the room. If the cover is left in place, it should be thoroughly insulated to prevent condensation. The required temperatures can be more readily obtained by blanketing the transformer with heavy paper, cloth, building felt, etc.

Take liquid samples every four hours and make tests of the dielectric strength. Oil-filled transformers should be sampled from both the top and bottom. To determine the drying progress, plot curves of load current, top liquid temperature, and dielectric strength versus time. A decrease in dielectric strength indicates that moisture is passing from the windings and insulation into the insulating liquid. As the moisture is driven out of the liquid, the dielectric strength will increase, indicating that the drying process is progressing satisfactorily.

Continue the drying until four consecutive samples test at least 26 kv and preferably 30 kv or higher and until a satisfactory "cloud" test is obtained as outlined under "Moisture Content." When the drying operation has been completed, the liquid removed for sampling must be replaced. To avoid the possibility of entrapping air bubbles in the windings, it is recommended that the liquid be returned through the upper filter press connection.

MAINTENANCE

The condition of the external transformer surfaces should be examined at regular intervals. If it is found that weathering is taking place, the surface should be cleaned thoroughly and repainted with a good grade of durable paint recommended by the General Electric Company. Before painting refer to the pressure-relief device section of this instruction book for important caution statements.

If it should become necessary to untank the core and coils, remove the weld bead around the cover as outlined under "Removing and Rewelding Covers" and then remove the tap changer drive mechanism as explained under "Wedge-Type Tap Changer." Lift off the cover and drain the insulating liquid. Disconnect the winding leads at the bushings and remove the bushings using the procedure outlined under "Bushings." Remove the liquid level gage, top filter-press connection, thermometer well (on those where it protrudes into the tank), and any other parts which might get damaged or interfere with removal of the core and coils.

Take out the tanking wedges and remove the core and coil assembly. After reassembling the transformer, it may be necessary to conduct a drying run as explained in the preceding paragraphs. Questions concerning the necessity of drying a particular transformer should be referred to the nearest Sales Office of the General Electric Company.

REMOVING AND REWELDING COVERS

Welded covers can be removed by chipping out the weld bead with diamond-point chisels and a pneumatic hammer or by the oxygen gouging method. The latter method is considerably faster and is recommended for all welds of 5/16" and over where adequate precautions can be taken for the fire hazard which exists with oxy-acetylene cutting operations.

When removing the weld bead, the cover should be clamped to the tank flange to hold it in place and prevent chips or welding slag from entering the transformer. Protect all openings against the entrance of foreign matter. Before oxygen gouging on oil- or Pyranol-filled transformers, thoroughly flush out the air space inside the tank with *dry* nitrogen or carbon dioxide gas and maintain a small flow of the gas during the gouging operation.

The entire weld may be removed in

one pass, providing care is taken to avoid deep gouging of the edge of the cover or tank flange. The joint should be ground or chipped clean for rewelding before the cover is removed. Oxyacetylene cutting torch equipment is necessary with gouging tips similar to Air Reduction Style No. 183. For best performance of the gouging operation, a cutting torch similar to Airco Series 3000 having a graduated control of the high-pressure oxygen flow is recommended. Tip sizes and gas pressures recommended for various fillet weld sizes are as follows:

Fillet Weld Size	Tip Size	Oxygen Pressure	Acetylene Pressure
5/16-in.	No. 8	60 psi	8 psi
3/8 and 7/16-in.	No. 10	70 psi	9 psi
1/2-in. and up	No. 12	75 psi	9 psi

REWELDING THE COVER

Before replacing the cover, remove all traces of dirt, grease, and oil from the areas to be welded. Cement a gasket to the tank flange or cover by applying a coat of water glass (sodium silicate) to both surfaces. The gasket should consist of a piece of 3/8-inch loose-twist glass or asbestos roving or a strip of 1/16 x 1½-inch dry asbestos folded to make it ¾-inch wide and should be located approximately ½-inch from the outer edge of the cover. To prevent spatter from entering the transformer during rewelding, compress this gasket by clamping the cover against its mounting flange and seal off all other external openings in the tank. Thoroughly flush out the air space with dry nitrogen and maintain a small flow of gas during the welding operation.

The arc-welding process, using 3/16" or ¼" diameter electrodes, is recommended for rewelding the cover. The fillet should be built up with a series of passes to a thickness comparable to that of the original weld. In order to make a pressure tight joint, slag and spatter should be completely removed before each succeeding pass and at each point where the arc is interrupted.

When the welding has been completed, remove all scale and pressure test the joint as explained under "Leak Test." After a satisfactory test, clean the weld and adjacent surfaces and apply one priming coat and two finish coats of paint.

RENEWAL PARTS LIST

Item Number	Description
101	High-Voltage Bushing
102	Low-Voltage Bushing
103	Neutral Bushing
104	Liquid Temperature Indicator
105	Liquid Level Gage
106	Prssure-Vacuum Gage
107	Fan
108	Fault-Pressure Relay
109	Gaskets, High-Voltage Bushing
110	Gaskets, Low-Voltage Bushing
111	Gaskets, Neutral Bushing
112	Gaskets, Liquid Temp. Ind.
113	Gasket, Liquid Level Gage
114	Gasket, Fault Pressure Relay
115	Gasket, Drain Valve
116	Gaskets, Tap Changer
117	Gasket, Pressure-Relief/Handhole

Refer to the transformer outline drawing for the location of these parts and for any unlisted items. Note that neutral bushings, fans, and the fault-pressure relay are optional features and may not be included with all transformers.

Orders for Renewal Parts should be placed with the nearest Sales Office of the General Electric Company. Specify the quantity required and give the TRANSFORMER SERIAL NUMBER, and DESCRIPTION of the desired parts. If the required items are not identified on this list or the outline drawing, describe the part(s) in detail and include the SERIAL NUMBER of the TRANSFORMER.

Materials that are unaffected by Pyranol have been used in constructing Pyranol transformers and no substitution should be made for these materials without the approval of the General Electric Company. Any renewal parts supplied will be manufactured from the same or similar materials as those used for new transformers. Successful operation of the renewal parts is contingent upon proper field assembly, the condition of the remaining parts and a thorough drying cycle if moisture has entered the transformer.

WHEN YOU NEED SERVICE

If you need to repair, recondition, or rebuild any electric apparatus, a GE Service Shop near you is available day or night, seven days a week, for work in the shop or on your premises. Latest factory methods and genuine GE renewal parts are used to maintain the original performance of your GE equipment. For full information about these services, contact the nearest Sales Office or General Electric Service Shop.

MEDIUM TRANSFORMER DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

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Replacement of Re-X Glass Ceramic Bushing Shells

INTRODUCTION

The changing of a bushing shell without removing its stud is not a difficult operation if a combination of reasonable care and proper technique is used. A study of the bushing cross section, as shown in Fig. 1, will aid the operator in understanding the operation. A quality job will result when the operator understands and has confidence in the method described. Proper equipment and technique has been the major trouble in carrying out this operation in the field. A complicated welding machine with high frequency start, gas valve control and other special circuits is not required to do this job. A simple, easy-to-obtain set up will be shown and described. The technique requires a steady hand, but a competent welder, following the procedure recommended, can do a good job. A short practice session on scrap material is a good idea if the welder is not familiar with thin material T.I.G. (Tungsten-Inert-Gas) welding. It is recommended that the following instructions be studied prior to beginning actual work.

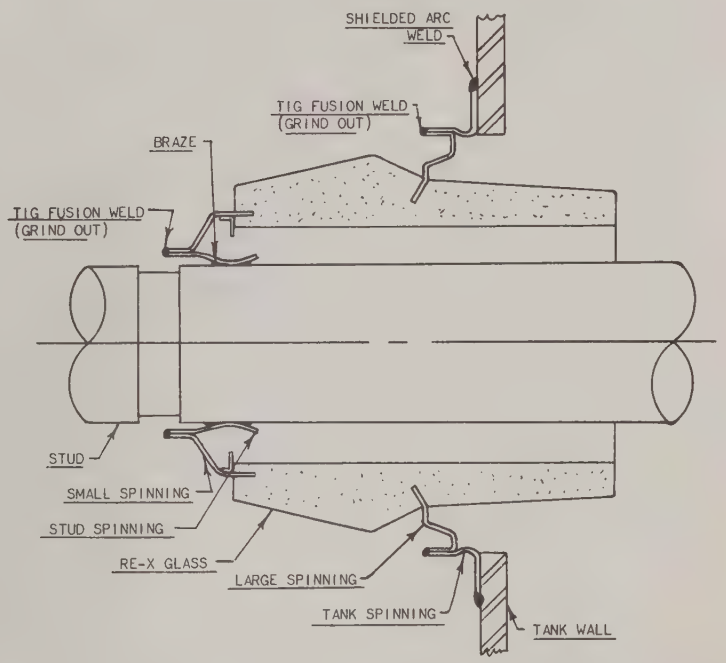

Fig. 1. Cross section of bushing

EQUIPMENT DESCRIPTION

The following items of equipment are required for removing and replacing Re-X glass ceramic bushing shells. Typical major components are illustrated in Fig. 2.

1. Grinder - Electric or air-driven

2. Disc - Small 4" with fine grit surface (rotary file may be used in place of grinder)

3. Chisel - ⅜" to ½" wide cold chisel

4. Hammer - Small ball peen

5. Power Supply - Constant current (for stick electrode) direct current welder. May be portable generator or transformer-rectifier type.

6. Argon Supply - Cylinder, regulator and flowmeter.

7. Torch Unit - 100 to 130 amp torch outfit for T.I.G. welding, air cooled with gas control valve in handle. TEC Company Model No. 3222-25V (206 V Torch) or No. 3442-25V (207V torch) at $100 and $125 are excellent.

8. Welding Hood - Medium lens

9. Pliers - Needle-nose

PROCEDURE

REMOVING OLD SHELL

The two welds must be removed by grinding through to allow bushing separation from tank. Grind only to the depth required which will be less than .050". Exercise extreme care not to damage adjacent bushings or spinner parts that remain to be re-used. Bending and excessive metal removal will make it difficult to install the new bushing shell. Part of the weld on the large spinning may not be safely ground out with the bushing in place. In this event, grind out accessible joint and use the chisel to cut the bushing shell flange to allow removal of bushing shell. Clean the spinning and leave no moisture, dirt or grease on the surfaces near the joint.

INSTALLING NEW SHELL

Place the new shell over the stud and push into position. Use needle-nose pliers to get best fit and equal clearance around joint. Tack weld at four points spaced 90° apart to hold parts in position during welding. T.I.G. welding is done by controlling an electric arc in a gas shielded atmosphere to fuse the metals together. The gas shield is supplied by a regulated flow of 10 to 15 cubic feet per hour. Plywood or canvas windbreakers may be needed to protect gas shielding when welding outside on a windy day. The current used must be high enough to quickly melt the metal but not high enough to burn

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

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Fig. 2. Typical T.I.G. welding equipment

through. Forty amps may be used on the large spinning, but the small spinning must be done with 8 to 15 amps and the 40 amp setting for the large spinning must not be accidentally used on the small spinning. The Tungsten electrode should be set in the torch to extend out of the cup by 1/16 to ⅛" to allow for "scratch" starting of the arc. A short, constant length arc must be used.

Weave the torch to make the two metals of the joint flow together. When good wetting its achieved, the puddle can be carried around the unit easily by varying the arc time on each side of the joint to obtain proper heat distribution. The large stud acts as a heat sink on the braze of the small spinning and the braze of the small spinning will not be disturbed if proper heat and good torch travel technique are used in making the weld. The system of gas flow control using the valve on the torch is as follows: Open the torch valve and set proper flow rate on regulator flowmeter. Close the torch valve and control gas flow during weld time by opening the torch valve. Welding machine is to be connected straight polarity, electrode to negative terminal.

TROUBLE SHOOTING

If troubles are encountered in making the fusion weld between flanges, one or more of the following problems may exist. A number of possible causes are listed for each condition.

POROSITY

- Loss of gas shield
- Oil or dirt present
- Electrode touching weld puddle
- Torch travel too fast
- Arc not stable

POOR ARC STABILITY

- Improper ground (ground should be attached to spinning being welded)
- Loose torch lead connection
- Arc length being held too close or too long
- Gas not on

BURN THRU

- Current too high
- Oil or dirt present
- Poor fit up (keep edge joint surfaces as close as possible)
- Torch travel too slow

MEDIUM TRANSFORMER DEPARTMENT

GENERAL ELECTRIC

ROME, GEORGIA

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Ventilated Dry-type Transformers

RECEIVING, HANDLING, AND STORING

RECEIVING

Upon receipt of the transformer, make an examination for any damage which may have occurred during shipment. If injury or rough handling is evident, file a damage claim with the transportation company and notify the nearest apparatus Sales Office of the General Electric Company. Tighten any parts which may have worked loose during shipment and check all materials against the shipping list for possible shortages. Accumulated dirt or dust should be wiped off accessible inside and outside surfaces and any visible dirt or dust on the windings or in the air ducts should be removed as explained under "Maintenance".

HANDLING

The transformer casing and base are designed so that the unit may be moved by lifting, rolling, skidding, or jacking.

1. Lifting can be accomplished by various means.

   A. The bolted-on lugs at the base allow the entire unit to be lifted. The point of lifting must be twice as high as the unit and suitable spreader bars should be used to avoid damaging the casing.

   B. If the cover is removed, the entire structure can be lifted from the top cross angles.

   C. The entire casing can be removed and the core and coils and base can be lifted as in "B" above.

   D. The base and casing can be removed and the core and coils lifted as in "B" above.

2. The unit can be rolled in either direction by rollers under the base, with or without the casing.

3. For skidding as well as rolling, pulling eyes are incorporated in the bolted-on lifting lugs.

4. The unit can be jacked from under the base angle at each corner.

STORING

If storage becomes necessary, the transformer should be placed in a clean, dry room in which a uniform temperature is maintained. Before placing the unit in service, check for dryness as outlined under "Operation".

INSTALLATION

This transformer is to be installed in such a manner and location as to minimize the hazards to all those who have access to it.

The equipment covered by these instructions should be installed operated, and serviced only by competent technicians familiar with good safety practices, and these instructions are written for such personnel and are not intended as a substitute for adequate training and experience in safe procedures for this type of equipment.

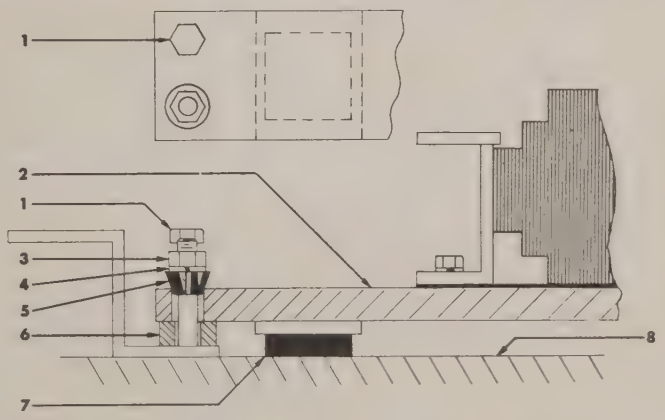
LOCATION

Ventilated dry-type transformers are designed for installation in dry locations, reasonably free of dust and chemical fumes. If the unit is to be installed in an atmosphere which includes corrosive agents, additional protective measures may be required. The transformers will operate successfully in a humid atmosphere, but precautions may have to be taken to keep them dry during shut down periods as explained under "Operation". Precautions should be taken to guard against entrance of water from any source such as roof leaks, broken water or steam lines, windows, etc. The bolt-on lifting lugs can be removed if desired and stored on the floor inside the casing. When supplied, terminal compartments can be removed to facilitate installation.

At higher altitudes, decreased air density reduces transformer cooling efficiency and lowers arc-over voltages. If the transformer is to be installed at an elevation above 3300 feet, consult the nearest apparatus Sales Office of the General Electric Company relative to its suitability for operation at the higher altitude.

VENTILATION

For adequate cooling the unit should be installed at least six inches and preferably a foot or more away from walls



1. JACK SCREW
2. CORE AND COIL CROSS MEMBER
3. TIE-DOWN NUT
4. SPRING WASHER
5. BEVELED SPACER
6. SHIPPING BLOCK
7. RUBBER VIBRATION ISOLATION PAD
8. FOUNDATION

Fig. 1. Detail of vibration isolation mounting showing shipping hardware and location of rubber pad

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

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and other obstructions which might prevent free circulation of air through and around the unit. Mechanical clearances should be taken into consideration in installing the transformer. Sufficient room should be allowed for removal of panels for cleaning and, with reverse arrangement of units, for changing of taps.

If the transformer is to be installed in a vault, provide ventilation which is adequate to keep the room temperature from exceeding that of the incoming air by more than 5 C. The number and size of air outlets required will depend on their distance above the transformer, and on the efficiency and load cycle of the apparatus. See ANSI Standard C57.94, "Guide for Installation and Maintenance of Dry-Type Transformers."

Arrange air inlets and outlets so that they are permanently open. Do not use as ventilators, windows or doors which may be opened and closed by attendants because of the danger of excessive heating in case they are inadvertently left closed during periods of heavy load or high temperature. If forced ventilation is used, supply about 5000 cubic feet of air per minute for each 1000 kVA of transformer capacity, and conduct the incoming air directly to the transformer.

VIBRATION ISOLATION PADS

Rubber vibration isolation pads are an integral part of the transformer and are to be placed under the core and coil assembly during installation. Refer to Fig. 1 and proceed as follows:

1. Remove the front and back panels of the transformer casing, leaving the end panels to support the cover.

2. Remove the temporary tie-down hardware at the four points inside the transformer base. These items are painted red and include nut (3), spring washer (4), and beveled spacer (5).

3. Raise the core and coil assembly using jack screws (1) and remove temporary shipping blocks (6).

4. Place rubber vibration isolation pads (7) on the foundation directly under the cross members (2) as shown in Fig. 1.

5. Back off on the jack screws sufficiently to allow the core and coil assembly to float freely on the pads.

6. Items (3), (4), (5), and (6) should be stored for future use as they must be replaced before moving the transformer. If desired, these parts may be assembled on jack screw (1) for storage.

CONNECTIONS

When making connections between plated aluminum transformer terminals and copper or aluminum conductors of associated equipment, the following procedure is recommended.

Assemble a Belleville spring washer and a flat washer under the head of each bolt. Place the Belleville spring washer so that the concave surface is away from the bolt head and the periphery is on the flat washer. The flat washer prevents the outer edges of the Belleville spring washer from cutting through the plating and distributes the bolting forces.

Place a flat washer under the nut on the opposite side of the joint and tighten the nut until the Belleville spring washer is just flattened. (Washers are flattened when there is a noticeable increase in bolting torque.) After the nut has been properly tightened, it should be locked with a locking nut or such other locking device as may be furnished with the equipment being connected to the transformer.

When clamp-type terminals are assembled on plated aluminum bars, the same basic procedure given above should be followed except that the Belleville spring washer and flat washer should be placed between the nut on the eyebolt and the bar.

When connecting bus bars, be sure the joints are properly aligned prior to bolting to prevent excesive strain on the insulators. In a terminal chamber, long sections of unsupported conductor should be avoided and leads should be flexible enough to allow for expansion and contraction.

Suitable devices should be installed to protect the transformer from excessive overloads and if there is reason to suspect that the transformer will be subjected to overvoltages in excess of its BIL rating, additional protective equipment may be required. For specific recommendations, consult the nearest apparatus Sales Office of the General Electric Company.

GROUNDING

A ground pad with two tapped holes is provided on the end of the casing for connecting the transformer case to ground. A substantial and thoroughly reliable connection should be made between the pad and a low resistance ground through a conductor of adequate cross section.

The core and coil structure is connected to the ground pad by means of a flexible connector which comes out of the unit through the end panel. This connection must be tight at all times.

When a transformer is designed for use on a system having a solidly grounded neutral, be sure that the neutral lead is permanently and solidly grounded at all times.

CHANGING TAPS

The transformer is shipped connected for operation at the rated voltage shown on the nameplate unless otherwise requested by the user. Access for changing taps is provided by means of covered openings on the front panel (or back panel on reverse units). *De-energize the transformer before removing these covers or attempting to change taps. Make no connections other than those authorized by the nameplate.*

ALUMINUM TAP TERMINALS

Ventlilated dry-type transformers which have aluminum windings are equipped with aluminum tap terminals. Belleville spring washers are included in the tap terminal hardware. When taps are changed, the nuts should be tightened until these Belleville spring washers are flattened. Washers are flattened when there is a noticeable increase in bolting torque.

To prevent oxidation and maintain low contact resistance, aluminum tap terminals are coated with a joint compound which should not be removed. The terminals as received are free of oxides and taps may be changed at installation without any special precautions. If at some future time taps are changed, the following procedure is recommended.

1. Apply a light coat of silicone grease to contact surfaces on terminals and links.

2. Scrub the contact areas with a wire brush, taking care not to gouge the metal surfaces. This abrading will break up any oxides which may have formed.

3. Wipe clean and reapply a thin film of silicone grease.

4. Bolt connecting link in the new position and tighten the nut until the Belleville spring washer is flattened.

OPERATION

Before energizing a ventilated dry-type transformer either initially or after any shutdown period in which the unit has cooled to ambient temperature, the transformer should be inspected for evidence of moisture and the insulation resistance should be checked. (Absorption of moisture can be minimized during shutdown periods by using strip heaters to keep the transformer temperature above ambient.) An insulation resistance of 2 megohms (one minute reading at approximately 25 C) per 1000 volts of rated winding voltage, but in no case less than 2 megohms total, is a satisfactory value of resistance to permit energizing the transformer.

DRYING

If moisture is found on the windings,

leads, or insulation or if the insulation resistance measurements are unsatisfactory, the transformer should be dried by placing the core and coil assembly in a drying oven for approximately 15 hours at 150 C. An alternate method is to put a short circuit heat run on the unit by short circuiting the low-voltage leads and impressing impedance voltage on the high-voltage terminals. It may be necessary to impress a voltage higher than the impedance voltage in order to heat the windings sufficiently, but the temperature of the windings as determined by resistance should not exceed 150 C (or 145 C by spirit-type thermometer placed in the ducts between windings). The heat run should be continued for a minimum of eight hours. For further information on dry-in, refer to ANSI Standard C57.94, "Guide for Installation and Maintenance of Dry-Type Transformers".

MAINTENANCE

The transformer should be inspected at periodic internals and corrective measures taken when necessary. The frequency at which these inspections are made depends on operating conditions and the importance of continuity of service. In clean, dry locations an annual inspection may be adequate. In areas where the air is contaminated with dust or chemical fumes, three-month intervals may be required.

To inspect the transformer, de-energize the unit and remove the side panels. Inspection should be made for accumulation of dirt on insulating surfaces and in places which would restrict the flow of air, for loose connections, for the condition of terminal boards and for the general condition of the transformer. Observation should also be made for signs of overheating and of voltage creepage over insulating surfaces as indicated by tracking or carbonizing.

CLEANING

If dirt is found on the windings, insulators, leads or terminal boards, it should be removed to permit free circulation of air and to guard against the possibility of insulation breakdown. Particular attention should be given to cleaning top and bottom ends of winding assemblies and to ventilating ducts. The use of a vacuum cleaner is recommended as the first step in cleaning followed by the use of compressed air or nitrogen. The compressed air or nitrogen should be clean and dry and should be applied at pressures below 25 psi. Lead supports, terminals boards, and other major insulating surfaces should be brushed or wiped with a dry cloth. The use of liquid cleaners is not recommended because of the possible deteriorating effects on the insulating materials.

RENEWAL PARTS

Address orders for renewal parts to the nearest apparatus Sales Office of the General Electric Company. Include a complete description of the part wanted, plus the rating and serial number of the transformer.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

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6-73 (1M)

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Ventilated Dry-type Transformers

RECEIVING, HANDLING, AND STORING

RECEIVING

Upon receipt of the transformer, make an examination for any damage which may have occurred during shipment. If injury or rough handling is evident, file a damage claim with the transportation company and notify the nearest apparatus Sales Office of the General Electric Company. Tighten any parts which may have worked loose during shipment and check all materials against the shipping list for possible shortages. Accumulated dirt or dust should be wiped off accessible inside and outside surfaces and any visible dirt or dust on the windings or in the air ducts should be removed as explained under "Maintenance".

HANDLING

The transformer casing and base are designed so that the unit may be moved by lifting, rolling, skidding, or jacking.

1. Lifting can be accomplished by various means.

   A. The bolted-on lugs at the base allow the entire unit to be lifted. The point of lifting must be twice as high as the unit and suitable spreader bars should be used to avoid damaging the casing.

   B. If the cover is removed, the entire structure can be lifted from the top cross angles.

   C. The entire casing can be removed and the core and coils and base can be lifted as in "B" above.

   D. The base and casing can be removed and the core and coils lifted as in "B" above.

2. The unit can be rolled in either direction by rollers under the base, with or without the casing.

3. For skidding as well as rolling, pulling eyes are incorporated in the bolted-on lifting lugs.

4. The unit can be jacked from under the base angle at each corner.

STORING

If storage becomes necessary, the transformer should be placed in a clean, dry room in which a uniform temperature is maintained. Before placing the unit in service, check for dryness as outlined under "Operation".

INSTALLATION

This transformer is to be installed in such a manner and location as to minimize the hazards to all those who have access to it.

The equipment covered by these instructions should be installed operated, and serviced only by competent technicians familiar with good safety practices, and these instructions are written for such personnel and are not intended as a substitute for adequate training and experience in safe procedures for this type of equipment.

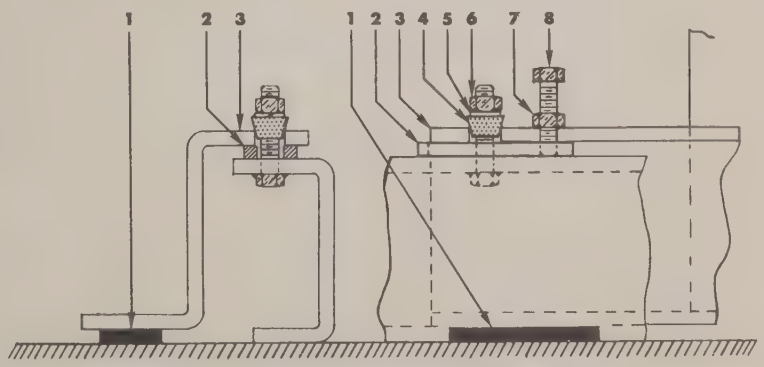
LOCATION

Ventilated dry-type transformers are designed for installation in dry locations, reasonably free of dust and chemical fumes. If the unit is to be installed in an atmosphere which includes corrosive agents, additional protective measures may be required. The transformers will operate successfully in a humid atmosphere, but precautions may have to be taken to keep them dry during shut down periods as explained under "Operation". Precautions should be taken to guard against entrance of water from any source such as roof leaks, broken water or steam lines, windows, etc. The bolt-on lifting lugs can be removed if desired and stored on the floor inside the casing. When supplied, terminal compartments can be removed to facilitate installation.

At higher altitudes, decreased air density reduces transformer cooling efficiency and lowers arc-over voltages. If the transformer is to be installed at an elevation above 3300 feet, consult the nearest apparatus Sales Office of the General Electric Company relative to its suitability for operation at the higher altitude.

VENTILATION

For adequate cooling the unit should be installed at least six inches and preferably a foot or more away from walls and other obstructions which might prevent free circulation of air through and around the unit. Mechanical clearances should be taken into consideration in



1. Rubber pad
2. Shipping block
3. Base "Z" bar
4. Beveled spacer
5. Spring washer
6. Tie-down nut
7. Locknut
8. Jack screw

Fig. 1. Installation detail of rubber vibration isolation pads

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installing the transformer. Sufficient room should be allowed for removal of panels for cleaning and, with reverse arrangement of units, for changing of taps.

If the transformer is to be installed in a vault, provide ventilation which is adequate to keep the room temperature from exceeding that of the incoming air by more than 5 C. The number and size of air outlets required will depend on their distance above the transformer, and on the efficiency and load cycle of the apparatus. See ANSI Standard C57.94, "Guide for Installation and Maintenance of Dry-Type Transformers."

Arrange air inlets and outlets so that they are permanently open. Do not use as ventilators, windows or doors which may be opened and closed by attendants because of the danger of excessive heating in case they are inadvertently left closed during periods of heavy load or high temperature. If forced ventilation is used, supply about 5000 cubic feet of air per minute for each 1000 kVA of transformer capacity, and conduct the incoming air directly to the transformer.

VIBRATION ISOLATION

Before placing the transformer in service, insert the four rubber vibration isolation pads under the transformer base. Locate a pad at each end of the two "Z" bars as follows (see Fig. 1):

1. Remove the front and back panels, leaving the end panels to support the cover.
2. Remove the following pieces which are painted red: tie-down nut (6), spring washer (5), and beveled spacer (4).
3. Loosen locknut (7) and raise core and coils with jack screw (8).
4. Remove shipping block (2) and insert rubber vibration isolation pad (1) under base (3). Also remove the four wooden shipping wedges (painted red) that may be located between the base and the high-voltage bus-bar supports. (These wedges are not shown on Fig. 1.)
5. Back off jack screw sufficiently to allow the core and coil assembly to float freely on pad (1).
6. Store items which were removed because they must be replaced before unit is moved. For convenience in storage, parts (2), (4), (5), and (6) may be assembled on jack screw (8) and tightened in place with locknut (7).

CONNECTIONS

When making connections between plated aluminum transformer terminals and copper or aluminum conductors of associated equipment, the following procedure is recommended.

Assemble a Belleville spring washer and a flat washer under the head of each bolt. Place the Belleville spring washer so that the concave surface is away from the bolt head and the periphery is on the flat washer. The flat washer prevents the outer edges of the Belleville spring washer from cutting through the plating and distributes the bolting forces.

Place a flat washer under the nut on the opposite side of the joint and tighten the nut until the Belleville spring washer is just flattened. (Washers are flattened when there is a noticeable increase in bolting torque.) After the nut has been properly tightened, it should be locked with a locking nut or such other locking device as may be furnished with the equipment being connected to the transformer.

When clamp-type terminals are assembled on plated aluminum bars, the same basic procedure given above should be followed except that the Belleville spring washer and flat washer should be placed between the nut on the eyebolt and the bar.

When connecting bus bars, be sure the joints are properly aligned prior to bolting to prevent excesive strain on the insulators. In a terminal chamber, long sections of unsupported conductor should be avoided and leads should be flexible enough to allow for expansion and contraction.

Suitable devices should be installed to protect the transformer from excessive overloads and if there is reason to suspect that the transformer will be subjected to overvoltages in excess of its BIL rating, additional protective equipment may be required. For specific recommendations, consult the nearest apparatus Sales Office of the General Electric Company.

GROUNDING

A ground pad with two tapped holes is provided on the end of the casing for connecting the transformer case to ground. A substantial and thoroughly reliable connection should be made between the pad and a low resistance ground through a conductor of adequate cross section.

The core and coil structure is connected to the ground pad by means of a flexible connector which comes out of the unit through the end panel. This connection must be tight at all times.

When a transformer is designed for use on a system having a solidly grounded neutral, be sure that the neutral lead is permanently and solidly grounded at all times.

CHANGING TAPS

The transformer is shipped connected for operation at the rated voltage shown on the nameplate unless otherwise requested by the user. Access for changing taps is provided by means of covered openings on the front panel (or back panel on reverse units). *De-energize the transformer before removing these covers or attempting to change taps. Make no connections other than those authorized by the nameplate.*

ALUMINUM TAP TERMINALS

Ventlilated dry-type transformers which have aluminum windings are equipped with aluminum tap terminals. Belleville spring washers are included in the tap terminal hardware. When taps are changed, the nuts should be tightened until these Belleville spring washers are flattened. Washers are flattened when there is a noticeable increase in bolting torque.

To prevent oxidation and maintain low contact resistance, aluminum tap terminals are coated with a joint compound which should not be removed. The terminals as received are free of oxides and taps may be changed at installation without any special precautions. If at some future time taps are changed, the following procedure is recommended.

1. Apply a light coat of silicone grease to contact surfaces on terminals and links.
2. Scrub the contact areas with a wire brush, taking care not to gouge the metal surfaces. This abrading will break up any oxides which may have formed.
3. Wipe clean and reapply a thin film of silicone grease.
4. Bolt connecting link in the new position and tighten the nut until the Belleville spring washer is flattened.

OPERATION

Before energizing a ventilated dry-type transformer either initially or after any shutdown period in which the unit has cooled to ambient temperature, the transformer should be inspected for evidence of moisture and the insulation resistance should be checked. (Absorption of moisture can be minimized during shutdown periods by using strip heaters to keep the transformer temperature above ambient.) An insulation resistance of 2 megohms (one minute reading at approximately 25 C) per 1000 volts of rated winding voltage, but in no case less than 2 megohms total, is a satisfactory value of resistance to permit energizing the transformer.

DRYING

If moisture is found on the windings,

leads, or insulation or if the insulation resistance measurements are unsatisfactory, the transformer should be dried by placing the core and coil assembly in a drying oven for approximately 15 hours at 150 C. An alternate method is to put a short circuit heat run on the unit by short circuiting the low-voltage leads and impressing impedance voltage on the high-voltage terminals. It may be necessary to impress a voltage higher than the impedance voltage in order to heat the windings sufficiently, but the temperature of the windings as determined by resistance should not exceed 150 C (or 145 C by spirit-type thermometer placed in the ducts between windings). The heat run should be continued for a minimum of eight hours. For further information on drying, refer to ANSI Standard C57.94, "Guide for Installation and Maintenance of Dry-Type Transformers".

MAINTENANCE

The transformer should be inspected at periodic internals and corrective measures taken when necessary. The frequency at which these inspections are made depends on operating conditions and the importance of continuity of service. In clean, dry locations an annual inspection may be adequate. In areas where the air is contaminated with dust or chemical fumes, three-month intervals may be required.

To inspect the transformer, de-energize the unit and remove the side panels. Inspection should be made for accumulation of dirt on insulating surfaces and in places which would restrict the flow of air, for loose connections, for the condition of terminal boards and for the general condition of the transformer. Observation should also be made for signs of overheating and of voltage creepage over insulating surfaces as indicated by tracking or carbonizing.

CLEANING

If dirt is found on the windings, insulators, leads or terminal boards, it should be removed to permit free circulation of air and to guard against the possibility of insulation breakdown. Particular attention should be given to cleaning top and bottom ends of winding assemblies and to ventilating ducts. The use of a vacuum cleaner is recommended as the first step in cleaning followed by the use of compressed air or nitrogen. The compressed air or nitrogen should be clean and dry and should be applied at pressures below 25 psi. Lead supports, terminals boards, and other major insulating surfaces should be brushed or wiped with a dry cloth. The use of liquid cleaners is not recommended because of the possible deteriorating effects on the insulating materials.

RENEWAL PARTS

Address orders for renewal parts to the nearest apparatus Sales Office of the General Electric Company. Include a complete description of the part wanted, plus the rating and serial number of the transformer.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT
GENERAL ELECTRIC COMPANY
ROME, GEORGIA 30161

GENERAL ELECTRIC

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Sealed Dry-Type Transformers

NITROGEN-FILLED

RECEIVING, HANDLING AND STORING

RECEIVING

Sealed dry-type transformers are shipped filled to a slight positive pressure with dry nitrogen gas which, in service, serves as an insulating and cooling medium. Normally, the pressure-vacuum gage is shipped in place on the transformer. If the gage was removed and packaged separately for shipment, it should be installed before the transformer is put into service. The coupling on the gage assembly should be tightened "finger" tight with an additional one-eighth to one-quarter turn with a wrench. The tank pressure should then be observed. Fig. 1 shows the variation of tank pressure with ambient temperature for four specific nameplate filling pressures when the transformer is de-energized. For example, if 1 psi at 25 C were specified on the transformer nameplate and the ambient temperature were 40 C, the gage should read approximately 1.8 psi. If the ambient temperature were —20 C, the gage should read approximately 2.8 inches of mercury vacuum. Interpolation will be necessary for nameplate pressures between those shown in Fig. 1. If the tank pressure differs from the nameplate value corrected to the existing ambient temperature, corrective measures should be taken to restore it as described under "Flushing and Filling."

Make an external inspection of the transformer when received and tighten any parts which have worked loose during shipment. Inspect bushings for chipped or cracked porcelains. Unless there is evidence of damage during transit, an internal inspection will not be required.

If the transformer is opened in a humid atmosphere for inspection or to change taps, it should be flushed and refilled with dry nitrogen gas as explained under "Flushing and Filling." Flushing should not be necessary if the unit has been opened for a short time in a clean, dry atmosphere.

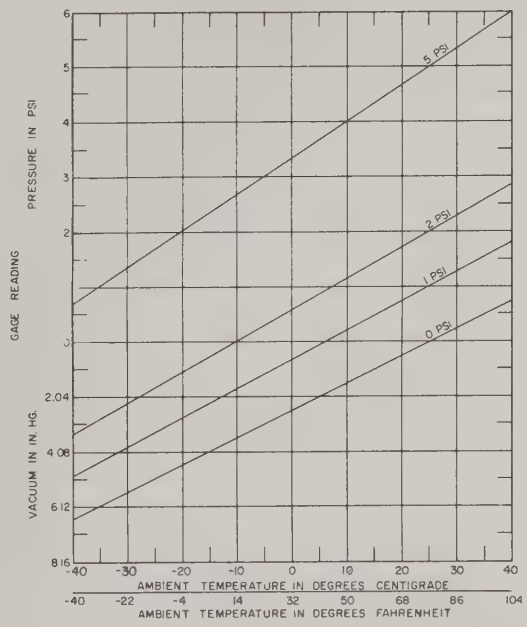

Fig. 1. Variations in internal gas pressure with changes in ambient temperature for a de-energized transformer

HANDLING

Lugs are provided for lifting the complete transformer and where necessary, provisions are made for lifting the various parts. Lift the transformer by means of the main lifting lugs using cables long enough to obtain cable pull angles not over 30 degrees from vertical. (If the transformer is to be lifted with its cover removed use a spreader bar to obtain a vertical lift or tack-weld the cover in place to prevent buckling the tank walls.)

The base is so constructed that the transformer can be skidded or moved on rollers in either direction. Jacking and pulling facilities are also provided. The transformer may be tipped on side or ends for movement through restricted passages provided care is taken to prevent jolting or jarring. Do not attempt to move the transformer by means of filling valves or other attachments.

STORING

No special storage precautions are necessary except to provide mechanical protection for bushings, valves and similar protrusions. The transformer internal gas pressure should be checked when placed in storage and again when removed and if evidence of a leak is found, the unit should be checked for dryness as explained under "Operation".

INSTALLATION

The only foundation necessary is a level floor strong enough to support the weight of the transformer. The transformer can be installed either indoors or outdoors and should be located at least six inches and preferably a foot or more away from walls and other obstructions which might prevent free circulation of air around the unit. Transformer finishes and components are designed for normal life in a non-corrosive atmosphere. Atmospheres

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which include corrosive agents may require additional protective measures.

Drilled flanges are provided on both the high- and low-voltage ends of the transformer for making connections to switchgear or terminal compartments. Terminal compartments, when provided, can be removed to facilitate installation of the transformer. To disassemble a compartment, remove the bolts around the edge of the front panel and pull it away at the bottom until the top slides out from under the cover. The cover and side panels can then be removed as required.

CONNECTIONS

It is recommended that the procedure outlined below be followed when connections are made between silver plated aluminum transformer terminals and copper or aluminum conductors of associated equipment.

1. Remove grease or other protective surface coating from terminals which are to be connected to the transformer. To these cleaned surfaces, apply a thin film of silicone grease. Unless there is evidence of dirt or other contamination, removal of the factory-applied silicone grease from transformer terminals will not be necessary.

2. Assemble a Belleville spring washer and a flat washer under the head of each bolt. Place the Belleville spring washer so that the concave surface is away from the bolt head and the periphery is on the flat washer. The flat washer prevents the outer edges of the Belleville spring washer from cutting through the silver plating and distributes the bolting forces.

3. Place a flat washer under the nut on the opposite side of the joint and tighten the nut until the Belleville spring washer is just flattened. After the nut has been properly tightened, it should be locked with a locking nut or such other locking device as may be furnished with equipment connected to the transformer.

4. Coat all parts of the joint with silicone grease. Be sure the demarcation lines between silver plating and aluminum are completely covered with silicone grease.

When clamp-type terminals are assembled on silver-plated aluminum bars, the same basic procedure given above should be followed except the Belleville spring washer and a flat washer shall be placed between the nut on the eyebolt and the bar.

When the transformer has silver plated aluminum terminals, the necessary Belleville spring washers, flat washers, and silicone grease will be supplied with the transformer. Bolts, nuts, and locking devices will be supplied with switchgear or other associated equipment. If the transformer terminals are copper, all hardware needed for making interconnections will be furnished with the switchgear or associated equipment.

When connecting bus bars, be sure the joints are properly aligned prior to bolting to prevent excessive strain on the bushings. In a terminal chamber, long sections of unsupported conductor should be avoided and leads should be flexible enough to allow for expansion and contraction.

Transformers having internal tap terminal boards are shipped connected for operation at the *rated* voltage shown on the nameplate unless otherwise requested by the user. Handhole covers located on the side of the tank provide access for changing tap links. *De-energize the transformer before removing these covers or attempting to change taps.* Make no connections other than those authorized by the nameplate.

Dry-type transformers which have aluminum windings are equipped with aluminum tap terminals and bushings. To prevent oxidation and maintain low contact resistance, tap terminals and bushings are coated with a joint compound which should not be removed. Contact surfaces as received are free of oxides and taps or bushing connectors may be changed without any special precautions. If at some future time taps or bushing connectors are changed, the following procedure is recommended.

1. Apply a light coat of silicone grease to contact surfaces on tap terminals and links or on the threads of connectors and bushing studs.

2. Scrub contact areas on tap terminals or threads on bushing studs and connectors with a wire brush taking care not to gouge the metal surfaces. This abrading will break up any oxides which may have formed.

3. Clean and reapply a thin film of silicone grease.

4. Bolt connecting link or connector in place. Tighten nuts until Belleville spring washers, supplied with the hardware, are flattened. Washers are flattened when there is a noticeable increase in bolting torque.

Replace bolted handhole covers in accordance with the procedure given under "Gaskets". Welded covers can be removed and replaced as explained under "Removing and Rewelding Covers".

Suitable devices should be installed to protect the transformer from excessive overloads and from overvoltages due to lightning and other surges. Consult the nearest Apparatus Sales Office of the General Electric Company for specific instructions.

Grounding

A ground pad with two tapped holes is provided for connecting the transformer case to ground. A substantial and thoroughly reliable connection should be made between the pad and a low resistance ground through a conductor of adequate cross section. When a transformer is designed for use on a system having a solidly grounded neutral, be sure that the neutral lead is permanently and solidly grounded.

GASKETS

Several different types of gaskets are used on the transformer and no substitutions should be made for these original gasket materials without the approval of the General Electric Company. Replacement or spare gaskets can be purchased to size through the nearest Apparatus Sales Office of the General Electric Company. Identify the parts wanted as explained under "Renewal Parts".

All of the gaskets used to maintain the transformer seal can be reused many times unless damaged. Before installing a new gasket or replacing an old one, thoroughly clean the gasket surfaces. No stickers are to be used with these gaskets, but if necessary, small clips may be used to hold them in place during assembly. Compress the gasket approximately one-third, or to the stops when provided in either the mating parts or in the gasket itself. Gaskets are compressed to the stops when there is a noticeable increase in the torque required to tighten the bolts. A leak test is recommended following the opening and closing of any gasketed joint affecting the transformer seal.

WEATHERPROOF JOINTS

A length of sponge rubber gasket is furnished with each outdoor unit with switchgear for the purpose of weatherproofing the flanged joints. Install this gasket just outside the mounting studs or bolt holes and for the best weather-resistant joint allow the piece across the top to overlap the two side pieces.

To install a sponge rubber gasket, clean the surface on which it is to be mounted and apply a thin coat of the adhesive furnished with the gasket to both the metal and the gasket.(Do *not* apply adhesive to the edges or outside surface of the gasket.) Allow the adhesive to dry until it is no longer tacky and then press the gasket against the metal with enough pressure to make a good contact.

When a retaining strip is provdied the gasket should be assembled with its inner edge in contact with the strip. Tighten the gasket down to this stop

or in the absence of a stop, compress it to approximately ½ size.

OPERATION

The transformer should be checked for dryness before being energized if there is any reason to suspect that moisture has entered the unit (as a result of an inspection or change of taps in a humid atmosphere or through a leak while the unit was in transit or storage, etc.) This can be done by making an insulation resistance test. A resistance of 2 megohms (one minute reading at approximately 25 C) per 1000 volts of rated winding voltage, but in no case less than 2 megohms total, indicates that the transformer is in satisfactory condition. Readings below these values should be questioned and if drying becomes necessary, consult the nearest Apparatus Sales Office of the General Electric Company for recommendations on the procedures to be followed.

Sealed dry-type transformers may be operated at rated load on any voltage tap. The operating temperature of the transformer winding is determined by the load it carries, its thermal characteristsics and the temperature of its cooling medium. Heavy loads of short duration may produce the same winding hot-spot temperature as lighter loads of longer duration. Although sealed dry-type transformers have high overload capacity, overloads of sufficient magnitude and duration may cause excessive heating. Excessive heating will result in insulation deterioration which reduces normal life.

The overload capacity is limited not only by winding hot-spot temperature but also by the tank pressure. When the transformer is excited, but with no load connected, the tank pressure will rise approximately 1 to 2 psi above the initial filling pressure corrected to existing ambient temperature (see Fig. 1). The tank pressure will increase to approximately 7 psi when the transformer is operating at rated load. On overloads, the pressure will increase in proportion to the increase of inside gas temperature. There should be no permanent tank distortion with pressures up to 10½ psi, and it is recommended that this pressure not be exceeded.

Although it is recommended that a sealed dry-type transformer be operated filled with dry nitrogen gas under pressure, the transformer may be operated with no pressure.

MAINTENANCE

The condition of the external transformer surfaces should be examined at regular intervals. If weathering or corrosion is found, the surface should be thoroughly cleaned and repainted with a good grade of durable paint recommended by the General Electric Company.

Regular checks should be made to insure a positive pressure reading on the pressure-vacuum gage. If the reading should fall below the initial nameplate filling pressure, or if there is any other reason to suspect a leak, a simple test can be made by applying a liquid soap solution to all suspected areas and checking for bubbles. The solution should be applied with a squirt can or similar device to avoid formation of bubbles during application and should be washed off afterwards to prevent streaking the paint finish. Do not introduce Freon-12 or any other material into the transformer for leak testing purposes, as it may have a harmful effect on certain components. After the leaks have been located and repaired, refill the transformer as outlined under "Flushing and Filling".

FLUSHING AND FILLING

If the transformer interior has become contaminated with outside air, it should be flushed and refilled to the initial nameplate filling pressure. Use *dry* nitrogen gas with a dew point below minus 40 F.

To flush the transformer, attach the line from the gas cylinder to the nipple on the connector provided. After flushing the gas cylinder lines, attach the connector to the fitting at the bottom of the tank. Tighten the coupling "finger" tight with an additional one-eighth to one-quarter turn with a wrench. Remove the pipe plug from the gas vent in the cover. Flush with approximately three times the gas volume appearing on the nameplate. After flushing, replace the pipe plug in such a manner as to be sure a pressure tight joint is obtained. Then, fill the transformer to the pressure given on the nameplate. Remove the connector at the bottom of the tank, and replace the caps to prevent foreign matter from entering the fittings.

Caution—When flushing or venting in a confined area, provide adequate ventilation to prevent possible asphyxiation of operating presonnel due to escaping nitrogen.

REMOVING AND REWELDING COVERS

Welded covers can be removed by chipping out weld bead with diamond-point chisels and a pneumatic hammer or by the oxygen gouging method. The latter method is considerably faster and is recommended for all welds of 5/16 inch and over.

To remove the cover, first relieve the internal gas pressure by removing the pipe plug from the gas vent in the cover. Leave the vent open during any welding operation. Clamp the cover to the tank flanges to hold it in place and prevent chips or welding slag from entering the transformer. Protect all openings against the entrance of foreign matter.

For best results in burning off a weld, a cutting torch, similar to the Airco Series 3000 with a gouging tip Style 183, No. 8, 10 or 12 is recommended. The entire weld may be removed in one pass and care should be taken to avoid deep gouging of the edge of the cover or tank flange. *The joint should be cleaned for rewelding before the cover is removed.* If the core and coil structure has been removed from the tank, care should be taken to replace it on the rubber pads used for vibration isolation.

Before replacing the cover, remove all traces of dirt and grease from the areas to be welded. Cement a gasket to the tank flange or cover by applying a coat of water glass (sodium silicate) to both surfaces. The gasket should consist of a piece of ⅜" loose-twist glass or asbestos roving or a strip of 1/16" x 1½" dry asbestos folded to make it ¾" wide and should be located approximately ½" from the outer edge of the cover. Clamp the cover to the flange during the welding operation to compress the gasket and prevent slag or spatter from entering the transformer.

The arc-welding process, using 3/16" or ¼" diameter electrodes, is recommended for rewelding the cover. The fillet should be built up with a series of passes to a thickness comparable to that of the original weld. In order to make a pressure tight joint, slag and spatter should be completely removed before each succeeding pass and at each point where the arc is interrupted.

When welding has been completed, remove all scale and pressure-test the joint at 7 psi using *dry* compressed air or *dry* nitrogen gas. Maintain the pressure and carefully inspect the weld for leaks using a liquid soap solution. After a satisfactory test, clean the weld and adjacent surfaces and apply one priming coat and two finish coats of paint. After sealing, thoroughly flush the transformer with *dry* nitrogen gas as described under "Flushing and Filling".

RENEWAL AND SUPPLY PARTS

Orders for renewal or supply parts should be placed with the nearest Apparatus Sales Office of the General Electric Company. Specify the quantity required and give the catalog or drawing number along with part numbers whenever possible. If these numbers are not available, describe the parts in detail. When requesting information or ordering parts for a particular transformer, always include the serial number appearing on the transformer nameplate.

MEDIUM TRANSFORMER PRODUCTS DEPARTMENT

GENERAL ELECTRIC

ROME, GEORGIA

10-75(1M)

PRINTED IN U.S.A.

Sealed Dry-Type Transformers

C_2F_6 GAS FILLED

RECEIVING, HANDLING AND STORING

Make an external inspection of the transformer when received and tighten any parts which have worked loose during shipment. Inspect bushings for chips or cracks. Unless there is evidence of damage during transit, an internal inspection will not be required. The pressure-vacuum gage shut-off valve is closed for shipment and should be opened upon receipt of the unit in order for the gage to indicate properly.

The transformer has been filled with C_2F_6 (Hexafluoroethane) gas to a pressure of 4 psig at 25 C. This gas serves as both an insulating and cooling medium and before placing the transformer in service, its pressure should be compared with the curve shown in Fig. 1. If the tank pressure is appreciably less than that shown by the curve for a given ambient temperature, check for leaks as explained under "Maintenance" and add make-up gas as required.

HANDLING

Lugs are provided for lifting the complete transformer and where necessary, provisions are made for lifting the various parts. Lift the transformer by means of the main lifting lugs using cables long enough to obtain cable pull angles not over 30 degrees from vertical. (If the transformer is to be lifted with its cover removed use a spreader bar to obtain a vertical lift or tack-weld the cover in place to prevent buckling the tank walls.)

The base is so constructed that the transformer can be skidded or moved on rollers in either direction. Jacking and pulling facilities are also provided. The transformer may be tipped on side or ends for movement through restricted passages provided care is taken to prevent jolting or jarring. Do not attempt to move the transformer by means of filling valves or other attachments.

STORING

No special storage precautions are necessary except to provide mechanical protection for bushings, valves and similar protrusions. Bushing shipping covers should be left in place during storage. The transformer internal gas pressure should be checked when placed in storage and again when removed and if evidence of a leak is found, the unit should be checked for dryness as explained under "Operation".

INSTALLATION

The only foundation necessary is a level floor strong enough to support the weight of the transformer. The transformer can be installed either indoors or outdoors and should be located at least six inches and preferably a foot or more away from walls and other obstructions which might prevent free circulation of air around the unit. Transformer finishes and components are designed for normal life in a non-corrosive atmosphere. Atmospheres which include corrosive agents may require additional protective measures.

Drilled flanges are provided on both the high- and low-voltage ends of the transformer for making connections to switchgear or terminal compartments. Terminal compartments, when provided, can be removed to facilitate installation of the transfomer. To disassemble a compartment, remove the bolts around the edge of the front panel and pull it away at the bottom until the top slides out from under the cover. The cover and side panels can then be removed as required. Protective covers on bushings should not be removed until unit is ready for connection in order to prevent damage to the bushings.

CONNECTIONS

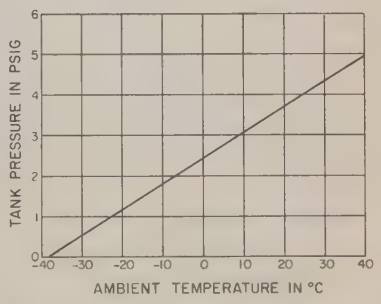
When connecting bus bars, be sure the joints are properly aligned prior to bolting to prevent excessive strain on the bushings. In a terminal chamber, long sections of unsupported conductor should be avoided and leads should be flexible enough to allow for expansion and contraction.

A ground pad with two tapped holes is provided for connecting the transformer case to ground. A substantial and thoroughly reliable connection should be made between the pad and a low resistance ground through a conductor of adequate cross section. When a transformer is designed for use on a system having a solidly grounded neutral, be sure that the neutral lead is permanently and solidly grounded.

GASKETS

Several different types of gaskets are used on the transformer and no substitutions should be made for these original gasket materials without the approval of the General Electric Company. Replacement or spare gaskets can be purchased to size through the nearest Apparatus Sales Office of the General Electric Company. Identify the parts wanted as explained under "Renewal Parts".

All of the gaskets used to maintain the transformer seal can be reused many times unless damaged. Before installing a new gasket or replacing an old one, thoroughly clean the gasket surfaces. No stickers are to be used with these gaskets, but if necesary, small clips may be used to hold them in place during assembly. Compress the gasket approximately one-third, or to the stops when provided in either the mating parts or in the gasket itself. Gaskets are compressed to the stops when there is a noticeable increase in the torque required to tighten the bolts. A leak test is recommended following the opening and closing of any gasketed joint affecting the transformer seal. (See "Maintenance".)



VARIATIONS IN INTERNAL GAS PRESSURE WITH CHANGES IN AMBIENT TEMPERATURE FOR A DE - ENGERGIZED TRANSFORMER FILLED TO 4 PSIG AT 25C.

Fig. 1. Pressure-temperature curve

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GENERAL ELECTRIC

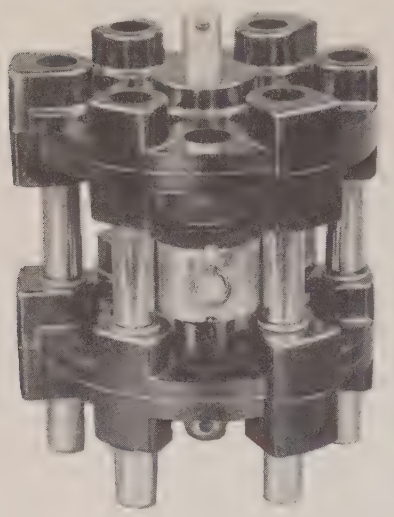


Fig. 2. Wedge-type tap changer

WEATHERPROOF JOINTS

A length of sponge rubber gasket is furnished with each outdoor unit with switchgear for the purpose of weather-proofing the flanged joints. Install this gasket just outside the mounting studs or bolt holes and for the best weather-resistant joint allow the piece across the top to overlap the two side pieces.

To install a sponge rubber gasket, clean the surface on which it is to be mounted and apply a thin coat of the adhesive furnished with the gasket to both the metal and gasket. (Do *not* apply adhesive to the edges or outside surface of the gasket.) Allow the adhesive to dry until it is no longer tacky and then press the gasket against the metal with enough pressure to make a good contact.

When a retaining strip is provided the gasket should be assembled with its inner edge in contact with the strip. Tighten the gasket down to this stop or in the absence of a stop, compress it to approximately ½ size.

ACCESSORIES

WEDGE-TYPE TAP CHANGER

The wedge-type tap changer, Fig. 2, provides a means of changing the voltage ratio of a de-energized transformer without breaking the transformer seal. It is shipped in place and is set on the position corresponding to the rated voltage shown on the transformer nameplate unless otherwise requested by the user.

Tap leads from the transformer windings are connected to a circular group of nickel-plated copper rods which are held together between two insulating heads. A wedge in the middle can be moved by a crankshaft to wedge between any two adjacent rods. A spring between the wedge and crankshaft maintains a high-presure line contact between current carrying components.

When the crankshaft is turned to move the wedge from one operating position to another, pressure is gradually reduced on the spring and the wedge is withdrawn from between rods. A "U"-shaped guide on the opposite side then pivots the wedge around to the next set of rods. As the crankshaft continues to turn, pressure is again applied to the spring and the wedge is forced into position with a wiping action, insuring positive contact.

The drive mechanism, Fig. 3, is located on the side or cover of the transformer and is connected through an insulator to the crankshaft of the tap changer. The cap covering the mechanism is gasketed to the mounting flange and an "O"-ring gasket is used between the mounting flange and drive shaft to maintain the transformer seal. One of the screws used to hold the cap in place has an oversize head with a hole in it for padlocking if desired. When requested, provisions can also be included for interlocking with the primary circuit breaker (or high-voltage disconnect switch) as explained under "Interlocks". Position indication is provided by an arrow on the mounting flange and a corresponding number on the cap.

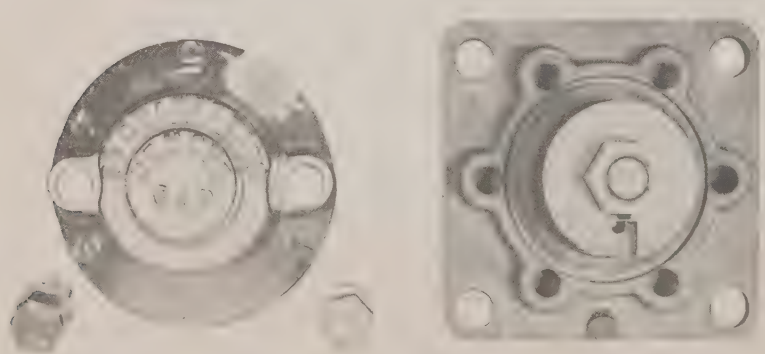


Fig. 3. Tap changer drive mechanism with cap removed

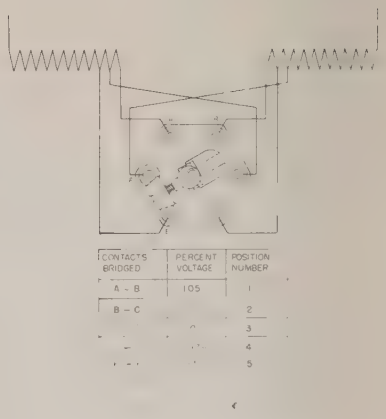


Fig. 4. Typical connection of a wedge-type tap changer

Operation

CAUTION! The tap-changer must not be operated while the transformer is energized! Serious personal injury and/or damage to the transformer may result if this is attempted.

Fig. 4 shows a typical connection arrangement for a five-position wedge-type tap changer having two steps above and two below the rated voltage of the transformer. A similar table on the transformer nameplate gives the voltage and current rating for each tap position.

To change taps REMOVE THE TAP CHANGER CAP and use a wrench to turn the hex-head drive mechanism. The mechanism must be rotated through 5/6 of a turn to make a change of one tap. With the cap removed, the tap position can be observed through a slot in the indicator cams (see Fig. 3). Although the drive mechanism can be turned continuously in either direction placing the wedge in any one of six different positions, only five positions are numbered for use as shown on the transformer nameplate. The unnumbered position is unauthorized and should not be used.

After the desired change has been made, make sure that the cap gasket is in good condition and replace the cap. Note that the slots in the two indicator cams must coincide before the cap can be seated properly. This is to insure that the cap is not replaced until the tap changer is on position and also serves to align an appropriate position number on the cap with the arrow on the mounting flange.

Interlocks

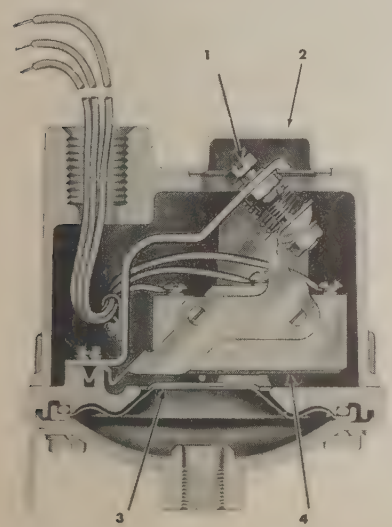
Upon request, the operating mechanism can be mechanically interlocked with the circuit breaker or disconnect switch feeding the transformer. This can be done either by means of a special

Fig. 5. Tap changer operating mechanism with key interlock

padlock inserted through the head of the oversize cap screw or by means of a captive key-operated plunger-type lock as shown in Fig. 5. The key for this lock is normally held in a similar lock on the primary circuit breaker and can be removed only by opening the breaker and locking it open. This de-energizes the transformer and permits the key to be removed and used to unlock the tap changer.

To place the transformer back in service after the desired tap change has been made, lock the tap changer in position, remove the key, and unlock and reclose the primary circuit breaker.

NOTE: A duplicate key is furnished with the transformer. This key is for emergency use only and should be removed from the operating area to insure the effectiveness of the interlock system.



1. Adjusting screws
2. Access cover
3. Metal diaphragm
4. Snap-action switches

Fig. 6. Cutaway view of pressure switch

Removing and Reassembling

If it becomes necessary to disconnect or remove a tap changer drive mechanism it should be placed on position 1 before removal in order to facilitate reassembly. (Also refer to "Gas Handling".) To remove the drive mechanism, unbolt the flange and lift the device out as an assembly. Note that drive mechanisms are not interchangeable! When two or more are removed at the same time, care should be taken to reassemble them in the same location from which they were removed.

When replacing, see that the tap changer and the drive mechanism are both on position 1. The tap changer is on position 1 when the wedge bridges tap leads A and B and the index marks on the drive shaft and support structure are in line with one another. To reassemble, place the drive shaft through the opening in the mounting flange and slide the coupling over the tap changer shaft. The slotted end of the coupling should engage a pin in the tap changer shaft without difficulty if both mechanisms are in the proper position.

After reassembling, check to see that the wedge seats itself properly in each position by observing the torque required to turn the drive mechanism in each direction. The mechanism will be at the center of a high torque region when the wedge is properly seated. If the device was correctly reassembled, the position indicator should accurately show the various positions.

Testing

Before placing a transformer in service, test the tap changer to determine that the positions are correct and the steps progress in accordance with the transformer nameplate. To do this, apply a low voltage to one winding and measure the voltage on the other winding for each tap-changer position. *CAUTION—The turns ratio must be taken into consideration when making this test, as voltages endangering the operating personnel may be present.*

PRESSURE SWITCH

The transformer is equipped with a pressure switch which can be connected to operate an alarm whenever the tank pressure exceeds predetermined operating limits. The pressure switch consists of a sealed metal diaphragm acting on a pair of snap-action switches as shown in Fig. 6. Switch No. 1 is set to operate at 14 psi on increasing pressure and switch No. 2 operates at 2 psi on decreasing pressure. Leads from the single-pole, double-throw switches can be identified as shown in Fig. 7 when the transformer pressure is in the normal operating range. (If the unit is examined at atmospheric pressure, switch No. 2 will have operated and contacts 4-5 will be closed and 5-6 will be open.) The switches will carry and interrupt the value of current listed in the following table.

Circuit	Type of Load	Circuit Volts	Amperes
AC	Inductive and Non-Inductive	115	10
		230	5
DC	Inductive	125	0.05
		250	0.03
	Non-Inductive	125	0.25
		250	0.20
AC or DC	Inductive	125 And 250	Restrict starting inrush currents to values below
			Already Closed Contacts: 30 — Closing Contacts: 15

The unit is factory calibrated and no changes in settings are recommended. However, if a change becomes necessary, calibrating screws are provided as shown in Fig. 6. The switches can be identified as No. 1 and No. 2 by removing access cover (2). To make adjustments, close the valve in the pressure line to the transformer, remove the device, and proceed as follows. NOTE—when applying pressure to the instrument for calibration purposes, do not exceed the proof pressure shown on the inside of cover (2).

1. Connect a test light to leads (1) and (2).

2. Apply a slowly increasing pressure and adjust the No. 1 calibrating screw until the light comes on at the desired setting.

3. Connect the test light to leads (4) and (5).

4. Starting with a pressure above that at which switch No. 2 is to operate, allow the pressure to decrease slowly and adjust the No. 2 switch as required.

5. Adjusting one switch may change the setting of the other slightly so it is usually necessary to repeat the calibrating procedure several times for each switch, making finer adjustments each time until both operate satisfactorily.

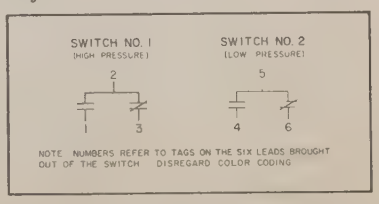


Fig. 7. Switch lead identification when transformer pressure is in normal operating range

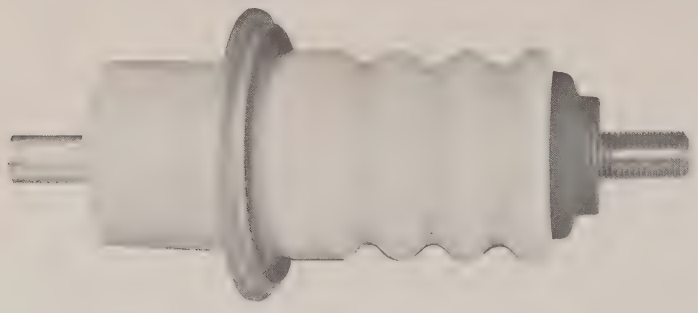


Fig. 8. Hermetically sealed Re-X bushing

BUSHINGS

High- and low-voltage winding leads are brought out through hermetically sealed Re-X glass ceramic bushings. See Fig. 8. A metal-to-glass seal is established in the bushing through the use of an oxide treat of the cap and mounting flanges prior to casting, plus a special glass ceramic material having a thermal co-efficient of expansion designed to match that of the metal. The cap flange is fusion welded to a spinning brazed on the bushing stud and the mounting flange is fusion welded to an adapter ring which in turn is welded to the transformer tank wall, thus completing the bushing seal without the use of gaskets.

When necessary, Re-X bushings can be removed externally. Instructions on the procedures to be used and the equipment required are contained in separate instructions GEK-5662, copies of which can be obtained through the nearest Apparatus Sales Office of the General Electric Company.

OPERATION

If there is reason to suspect that moisture has entered the transformer while in transit or storage, it should be checked for dryness before being energized. This can be done by making an insulation resistance test. A resistance of 2 megohms (one minute reading at approximately 25C) per 1000 volts of rated winding voltage, but in no case less than 2 megohms total, indicates that the transformer is in satisfactory condition. Readings below these values should be questioned and if drying becomes necessary, consult the nearest Apparatus Sales Office of the General Electric Company for recommendations on the procedures to be followed.

Transformers filled with C_2F_6 may be operated at rated load on any voltage tap. The operating temperature of the transformer winding is determined by the load it carries, its thermal characteristics and the temperature of its cooling medium. Heavy loads of short duration may produce the same winding hot-spot temperature as lighter loads of longer duration. Although C_2F_6 filled transformers have high overload capacity, overloads of sufficient magnitude and duration may cause excessive heating. Excessive heating will result in insulation deterioration which reduces normal life.

The overload capacity is limited not only by winding hot-spot temperatures but also by the tank pressure. On overloads, the pressure will increase in proportion to the increase of inside gas temperature. There will be no permanent tank distortion with pressures up to 15 psig and it is recommended that this pressure not be exceeded.

C_2F_6 GAS

C_2F_6 gas is approximately 5 times as heavy as air and although it mixes with air it tends to settle in low areas. C_2F_6 is not in itself toxic, but when it replaces air it can cause asphyxiation. Therefore, before entering an area with little or no circulation, an adequate supply of fresh air should be provided to insure against possible asphyxiation.

Although in normal use, C_2F_6 is an exceptionally stable compound, it will decompose to some extent when exposed to temperatures above 600 C. Since a portion of the decomposition products may be hazardous, excessive temperatures should be avoided whenever possible. When this is not possible, a plentiful supply of fresh circulating air is recommended.

In the event of internal arcing a portion of the gas, the amount depending on the severity of the arcing, will decompose. Before opening such a transformer for inspection and repair, the gas should be removed and dispersed widely in the outdoor atmosphere followed by flushing of the unit with fresh air.

PHYSICAL PROPERTIES

Molecular weight	138
Boiling point	—78C
Freezing point	—101C
Vapor density at one atm abs	0.358 lb/cu ft at 24C

MAINTENANCE

The condition of the external transformer surfaces should be examined at regular intervals. If weathering or corrosion is found, the surface should be thoroughly cleaned and repainted with a good grade of durable paint recommended by the General Electric Company.

Regular checks should be made to insure a positive pressure reading on the pressure-vacuum gage (make sure shut-off valve is open). If the reading should fall below the initial nameplate filling pressure or if there is any other reason to suspect that the transformer is losing gas, it should be inspected for leaks. Although not highly sensitive to C_2F_6, a halogen leak detector will respond to this gas and can be used in locating leaks. (Do not introduce Freon-12 or any other material into the transformer for leak testing purposes, as it may have a harmful effect on certain components.) If a more sensitive test is desired, apply a liquid soap solution to all suspected areas and check for bubbles.

Small leaks in welded seams may be repaired by rewelding with the C_2F_6 gas remaining in the transformer, providing the area immediately surrounding the weld is kept below a dull red heat and the tank pressure is reduced to zero psig. If any extensive welding is to be done, the gas should be removed from the transformer to avoid its decomposition by the elevated welding temperatures.

GAS HANDLING

Before engaging in gas handling, read section above entitled "C_2F_6 Gas". When it becomes necessary to remove or add gas, make connections to the transformer through the gas valve by removing the ½-inch pipe plug. To operate this valve, remove the 1-inch pipe plug and use a screwdriver to turn the valve stem.

Removing

Although field salvage of C_2F_6 is not practical because of its low condensation temperature, its relatively low price makes it feasible to discard and replace it at a modest cost. Since C_2F_6 is about five times as heavy as air, a vacuum pump should be used to evacuate the transformer before any internal maintenance work is performed. Disperse the gas widely in the outdoor atmosphere and break the transformer vacuum with fresh air. A continous supply of fresh air should also be provided whenever workmen enter the tank.

Adding or Refilling

CAUTION—C_2F_6 is supplied in a high-pressure cylinder with a normal

loading density of 70 lbs/cu ft. In an ambient temperature of 100 F the cylinder pressure will be approximately 1600 psig and therefore a suitable regulator must be used to reduce this pressure to 15 psig when adding gas to the transformer.

Because of its high vapor pressure even in low ambient temperatures (e.g., 23 psig at —75F), heating of the cylinder itself is not expected to be necessary to obtain the required 15 psig delivery pressure. However, at temperatures below 70 F the cooling effect of the expanding gas may cause external moisture to condense and freeze inside the regulator mechanism. When adding substantial amounts of gas to the transformer, such as during a complete refilling, it may become necessary to heat the regulator and its output line to prevent this freezing from gradually shutting off the flow. An electric resistance heating tape wrapped around the regulator body and piping is recommended as the most effective procedure.

If the transformer has been exposed to the atmosphere, it must be evacuated to an absolute pressure of 1.1 inches of mercury (measured at the transformer and not at the vacuum pump unless shut down) prior to being refilled with gas. Before beginning the evacuation, make a thorough inspection of the transformer, vacuum pump, hose connections, filling equipment, etc. for leaks. Depending on their size, leaks can make it difficult to obtain the required vacuum, contaminate the new gas with air during refilling, and those in the transformer itself will, of course, permit a continuous leakage of gas thereafter.

If there is any concern about air having leaked into the transformer, arrangements can be made to have a sample analyzed for air content. If the unit was exposed to the atmosphere for a period of more than 12 hours, drying may be necessary. Questions concerning air content or the need for drying and the methods to be used should be referred to the nearest Apparatus Sales Office of the General Electric Company.

REMOVING AND REWELDING COVERS

After removing the C_2F_6 gas, welded covers can be removed by chipping out the weld bead with diamond-point chisels and a pneumatic hammer or by the oxygen gouging method. The later method is considerably faster and is recommended for all welds of 5/16" and over where adequate precautions can be taken for the fire hazard which exists with oxyacetylene cutting operations. When removing the weld bead, the cover should be clamped to the tank flange to hold it in place and prevent chips or welding slag from entering the transformer. Protect all openings against the entrance of foreign matter.

For best results in burning off a weld, a cutting torch, similar to the Airco Series 3000 with a gouging tip Style 183 or 185, No. 6 is recommended. The entire weld may be removed in one pass providing care is taken to avoid deep gouging of the edge of the cover or tank flange. *The joint should be cleaned for rewelding before the cover is removed.*

Before replacing the cover, remove all traces of dirt and grease from the areas to be welded. Cement a gasket to the tank flange or cover by applying a coat of water glass (sodium silicate) to both surfaces. The gasket should consist of a piece of 3/8" loose-twist glass or asbestos roving or a strip of 1/16" x 1½" dry asbestos folded to make it ¾" wide and should be located approximately ½" from the outer edge of the cover. Clamp the cover to the flange during the welding operation to compress the gasket and prevent slag or spatter from entering the transformer.

The arc-welding process, using 3/16" or ¼" diameter electrodes, is recommended for rewelding the cover. The fillet should be built up with a series of passes to a thickness comparable to that of the original weld. In order to make a pressure tight joint, slag and spatter should be completely removed before each suceeding pass and at each point where the arc is interrupted.

When welding has been completed, remove all scale and pressure-test the joint at 14 psi using *dry* compressed air or *dry* nitrogen gas. Maintain the pressure and carefully inspect the weld for leaks using a liquid soap solution. After a satisfactory test, clean the weld and adjacent surfaces and apply one priming coat and two finish coats of paint.

RENEWAL AND SUPPLY PARTS

Orders for renewal or supply parts should be placed with the nearest Apparatus Sales Office of the General Electric Company. Specify the quantity required and give the catalog or drawing number along with part numbers whenever possible. If these numbers are not available, describe the parts in detail. When requesting information or ordering parts for a patricular transformer, always include the serial number appearing on the transformer nameplate.

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ROME, GEORGIA 30161

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